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ELEMENTS

OF THE

ANATOMY, PHYSIOLOGY, AND HYGIENE

OF THE

HUMAN SYSTEM.

BY
JUSTIN R. LOOMIS, LL.D.,
President of the University at Lewisburg; Author of the Elements of Geology.

REVISED EDITION.

NEW YORK:
SHELDON AND COMPANY,
677 BROADWAY.
1872.

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The present edition has been revised throughout, but the only important changes have been in the chapter on digestion. The section on the individual muscles has been retained, but as an appendix. No considerable difficulty will be experienced in the use of this and former editions in the same class.

Joseph J. Little,
Stereotyper, Electrotyper, and Printer,
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PREFACE.

A KNOWLEDGE of human Anatomy and Physiology is not confined to the medical profession, nor to professed scholars. It has become a part of general education, and is always attainable in our advanced schools, both public and private. The study becomes professional when it is pursued to minute details, but the general structure of the body, the uses of the several parts, the conditions upon which their healthy action depends, and the circumstances by which such action may be interfered with, should be understood by all. The physical well-being of ourselves and of those with whom we stand connected, depends in a great measure upon our acquaintance with these laws of our organization.

It is the design of the following work to present these principles in a form adapted to class instruction.

The first object has been a suitable arrangement. Such an analysis of the objects and wants of the system is given as leads to an obvious classification of the organs of the body. This enables the learner to see at once what subjects are to be investigated, and in what order they naturally present themselves, and to know when his work is done. Until the facts of a science are thus arranged, upon some principle of relation, they do not constitute a science, and can serve no purpose either of practical application or of furnishing enjoyment or mental discipline.

The Physiology and Hygiene of the several classes of organs are so obviously associated with their structure, that it was thought better to introduce them in immediate connection with the anatomical descriptions. The repetition which would be almost necessary if they were treated in separate sections is thus avoided.

Many subjects of collateral interest have been presented in the form of notes. This has been done in order that the consecutiveness of arrangement in the text might not be interfered with.

The second object has been compression. It is one of the serious difficulties met with by teachers, that their text-books are not too comprehensive, but too large. In most of the branches of study, they should be of such size that they can be completed in a single term. And in addition to this, time enough should be allowed for thorough review. A subject that is worth studying is worth reviewing. The principles should not only be understood, but they should be repeated so many times that they cannot be forgotten. Every scholar should become so familiar with the subjects of his study as to be able to take up any of the parts, and give a ready and intelligible account of it.

Whenever conclusions rest upon reasoning which is complex and difficult, special effort has been made to render the expression of the reasoning as clear and little involved as possible. But to simplify and popularize it in any other way has not been attempted, nor would such a course be likely to secure for it additional favor. Hence, technical terms have not been discarded. In entering upon a new subject of study, the learner will necessarily meet with new terms, and it is best to employ those which express the ideas that are peculiar to the study with the greatest precision, and the least circumlocution. Science has a language in some respects peculiar to itself, and so has the counting-room and the farm. Each claims its own language, its technical terms, because the ideas to be expressed are peculiar and require such terms.

A glossary of technical terms has been combined with the index, and, as a matter of convenience to pupils, the pronunciation has also been marked.

The several subjects are so fully illustrated by figures, that teachers, it is believed, will not find it necessary to avail themselves of anatomical plates to facilitate instruction.

The author has endeavored to bring the important principles of extended treatises on these subjects into a sufficiently narrow compass, to divest them somewhat of the professional cast which they there assume, and put them into a form in which they will be intelligible to pupils, and to give them an arrangement that will show their connection with each other, as parts of a single branch of science. In attempting to do this he has been guided by his experience as a teacher for many years. He now offers the work to the public in the hope that it will meet the approval of those to whom the instruction of youth is committed.

NEW YORK, Jan. 1, 1858.

ANATOMY, PHYSIOLOGY, AND HYGIENE.

INTRODUCTION.

1. It is the *object* of Anatomy to describe the human body, the structure, form, and position of its several organs. It is the object of Physiology to describe the uses and relations of these organs. It is the object of Hygiene to develop the principles upon which the healthy action of these organs depends. The three may be kept distinct as departments of professional study; but, as branches of general education, they are more conveniently studied together.

2. In order to arrive at a convenient classification of these organs, it is necessary to consider the object for which the body is furnished. We, that is our minds, can exert no *direct control*[1] over the material objects around

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[1] This statement can scarcely need illustration. We cannot, for instance, by a mere exertion of the will, cause a book which lies before us to change its place. Such change can be made only by the application of physical force. Perhaps we might have been so constituted that we could have controlled directly other matter, as we do our bodies; but such power has not been given us, and those who pretend to possess it either deceive, in reference to the effect itself, or the effect is produced by the application of ordinary physical force, exerted in such a way as to elude our observation. The most successful efforts of jugglery are of this last kind. The skill consists mainly in the power which performers acquire of moving the

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1. What is the object of Anatomy? Of Physiology? Of Hygiene?
2. Why is a physical system necessary?

us. We do, more or less, control these objects; but it is by the body as an intermediate agent. How the mind is brought into relation with this portion of matter, the body, so that it acts in obedience to our wills, is unexplained and inexplicable. All that we can say of it is, that it has pleased our Creator thus to constitute us; and all the knowledge which we have of the external world comes to us by this connection of mind and body.

3. Bearing in mind, then, that the body is furnished us as the means by which we may become acquainted with, and operate upon, external objects, we may inquire what kind of organization will secure this end.

In the first place, there must be a suitable *mechanical structure.* It must be sufficiently firm to support the weight and transmit the power which the purposes of life require; and this firmness is secured by the framework of *bones* which the body contains. This framework must not be a rigid structure, but capable of various motions. The *joints* are provided, to render these motions possible; and the *muscles* are the system of connections by which the several parts of the frame are acted upon in the performance of these functions.

As a system of mechanism, the body is no more capable of moving itself than any other piece of machinery is. In the second place, then, the mind, regarded as the repository of voluntary power, must have the means of applying

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hands with wonderful accuracy, and yet with a rapidity so great that the eye cannot follow them. Thus, changes take place before the observer for which he can assign no cause; but they are effected by the hand of the performer with a motion which is invisible only because of its rapidity.

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3. What are the three systems of organs by which the body is fitted to perform its functions? Of what classes of organs does the mechanical system consist? Why must there be a nervous system? Of what classes of organs does it consist? Why is a third system of organs necessary? What objects are effected by the repairing system?

its power. The *nervous system*, consisting of the brain, the spinal cord, the nerves, and the organs of the external senses, are the means of applying this power to the mechanical system, as well as the means by which the mind acquires a knowledge of the properties of matter.

It would seem that when these two systems are formed, and so long as they remain perfect, no others are necessary to effect the purposes for which the body is designed. But a long process of growth is necessary to perfect the body; and, like all material structures, it is liable to become injured, and is subject to ultimate decay. It therefore becomes necessary that there should be a third system of organs, which we may call the *repairing system*, designed to secure the growth which is required in the earlier periods of life, and to furnish the repairs which are required at every period.

4. Our investigation of this subject will, therefore, be limited to an examination of these three systems, of which the body is mainly composed: namely, the Mechanical System, the Nervous System, and the Repairing System.

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4. To what will our study of this subject be limited?

PART I.

THE MECHANICAL SYSTEM.

THIS SYSTEM CONSISTS OF THE BONES, JOINTS, AND MUSCLES.

CHAPTER I.—OF THE BONES.

Section I.—General Considerations on the Bones.

5. **The principal object** of the bones is to constitute the framework of the body. Its firmness, height, and general form depend upon them. They, however, serve other important purposes, particularly that of protection to some of the more delicate organs. Thus, the cranium is designed to render the brain secure from external injury, and the ribs are employed to form and protect the cavity in which the heart and lungs are lodged.

6. It is interesting to trace **the process by which the bones are developed.** There is a period very early in our existence, but after the body has acquired its general form, when the skeleton contains no bone, but consists entirely of cartilage (**gristle**). These pieces of cartilage, which constitute the **first** draft of the osseous structure, are traversed by minute blood-vessels, and particles of bone, conveyed by the blood, are deposited at points

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Section I.—5. What is the principal object of the bones? What other purposes do they serve?

6. Of what is the first skeleton composed? State the process by which this is changed to one of bone. How long time is required to make this change?

called centres of ossification, near the middle of each piece of cartilage, the corresponding cartilaginous particles being at the same time taken up by the circulating fluid, and carried away.

Thus, by a very slow process, the original skeleton is taken down, and one of bone is built up.[2] Though ossification commences sometime before birth, it is not completed till about the twentieth year of life. In certain parts the change is delayed much longer. Thus, the lowest portion of the breast bone is generally cartilaginous till extreme old age, and the cartilages which connect the ribs with the breast bone, in healthy persons, never become ossified.[3]

7. At the most vigorous period of life, when the bones have attained their full development, they contain about three-fifths of their weight of earthy matter, of which phosphate of lime is the principal part, and the remaining two-fifths is animal matter, mostly in the form of gelatine.[4]

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[2] When children have but little exercise, breathe impure air, or are confined to food containing but little nourishment, the process of ossification is often arrested; and as the body, which continues to increase in size, becomes too heavy to be supported by the cartilages, they yield, and permanent deformity results.

[3] When a bone has been broken, it does not unite by a sudden deposition of bone. There is a partial cure effected by a rapid deposition of cartilage between the broken surfaces, by which they are temporarily, though not very firmly, united. The complete ossification of this cartilage may require several months.

[4] These two parts may easily be exhibited separately. When a bone is thrown into the fire, the animal matter which is distributed through it becomes charred (converted into charcoal) by the heat, and it becomes black. The animal matter, however, soon burns out, and a white brittle substance, the mineral matter of the bone, is left. The bones would,

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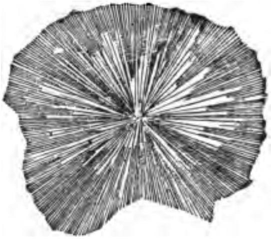
7. What is the composition of the bones? How does their composition differ from this in early life? Why is a flexible state of the bones better adapted to the conditions of early life? What change in the composition of the bones takes place in old age?

But their **composition** varies with a person's age. Early in life, the animal matter predominates, and the bones are tough and flexible, though possessing less of firmness. This is the reason why there are so few permanent injuries from the accidents of childhood and youth. In advanced life, the earthy matter predominates, and the bones become brittle, and, when broken, less disposed to unite firmly.

8. **The form** of the bones is so various, that it can scarcely be employed in the classification of them. Yet it is convenient to speak of long bones, as those of the leg; of flat bones, of which the cranium mostly consists; and of square bones, such as are found in the wrist and ankle.

9. **The structure** of the bones is by no means as simple as it at first appears. When bone begins to be formed, the osseous particles are so deposited as to form fine, stiff threads of bone, and hence the long bones are always fibrous, and, for the same reason, the flat bones have a radiated structure. (Fig. 1.)

Fig. 1.



Exhibiting the radiation of the flat bones.

The outside of the body of the long bones is very dense and compact; but, at a very little distance, the structure becomes porous, and the pores increase in size as they are situated further from the surface. Finally,

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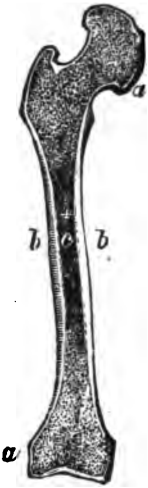
probably, become equally brittle during life if, by any vital process, they were as fully deprived of animal matter.

If a bone be placed in dilute muriatic acid, the acid will, in a few days, combine with and dissolve the earthy part of the bone, and leave the animal part, which will have the exact form and size of the bone, but will be flexible like India-rubber.

8. What classification of the bones is made depending upon their forms?
9. How are the fibrous and radiated structures produced? Where is the structure

Fig. 2.



Section of the thigh bone. *a a* The extremities, showing the spongy texture. *b b* The exterior of the body, of very dense bone. *c* The hollow of the bone, filled with marrow.

the centre is hollow. **The hollows** of the bones are filled with marrow, and the cavities of the porous portions are also filled with a fatty substance resembling marrow. By this arrangement, nearly as great strength is secured as would be if the whole were a mass of compact bone, while the weight is not more than half that of solid bone.

The extremities of the long bones, also, have the porous structure, and are much larger than the middle portions, in order to give strength to the joints by presenting large articular surfaces.

The substance of the bones is everywhere (except in the teeth) traversed by blood-vessels, absorbents, and nerves, so that these solid parts are still living parts, and are continually undergoing the processes of removal and renewal, like the other parts of the body.[5] It is by means of these traversing organs that the bones are able to unite when they have been fractured, or to be repaired when they have been injured by disease.

It follows, that children should not, before the bones have acquired their strength, be subjected to the severer kinds of labor, such as require great firmness of frame. They should not be required to lift great weights, nor carry heavy burdens; nor should they be confined, for a long time, to any one position. The restlessness of children is natural, and is designed to prevent the distortions of body which would be likely to result from a child's maintaining habitually the same position, when the bones are so

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most compact? What is the structure of the central portion of the bones? Of the extremities? Why are the extremities of the bones enlarged? With what are the cavities of the bones filled, and for what purpose? What other organs are found penetrating the bones, and for what purpose?

10. The blood always contains, in solution, a small amount of osseous matter, and both the formation and **growth of bones** take place by the deposition of these particles of bone. The bones increase in diameter by the

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yielding as to allow of their readily taking any form which a constrained position would tend to give.

Children at school often rest the elbows upon the table, and allow the head and chest to fall forward; they thus become round-shouldered Others acquire the habit of lounging, or of resting one elbow in such a way as to give a lateral curvature to the spine. The feeling of lassitude and weariness, which rapid growth is likely to induce, may encourage these and other objectionable positions which are liab'e to result in permanent deformity. The upright erect position may be recommended as preferable, so far as it can be practised; and yet this effort should not be carried too far, for, in the first place, to carry the head and shoulders too far back is as unnatural and as much a deformity as the opposite error; and, secondly, the most natural erect position will become injurious if persisted in to weariness. A large amount of exercise, and the frequent changes of position thus secured, are the best safeguards against all the deformities which are likely to be contracted in childhood.

[6] It will hereafter be shown that, by the processes of life, the soft parts are constantly undergoing removal and renewal. Portions of every muscle, for instance, are every moment undergoing chemical change, losing their vitality, and requiring removal from the system. At the same time, there is a renewal, by the deposition of new muscular fibre from the blood. These changes are essential to the continuance of life. It was discovered accidentally that the same changes take place in the bones. A dyer threw to some domestic animals madder from which most of the coloring matter had been extracted. Some of the coloring matter, however, remained, and upon killing the animals which had fed upon it, the bones were found to be tinged with it. Hence, there must have been a deposition of the coloring matter in the substance of the bone. By varying the experiment, feeding with madder, and then, for some time before killing, withholding it, the bones were found of the ordinary color; thus proving that the coloring matter which was at first deposited had been absorbed and removed.

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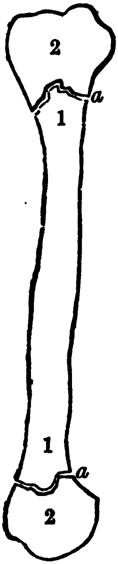
10. How is the osseous matter for the growth of the bones supplied? How do they increase in diameter? Why can they not increase in length in the same way? How do they increase in length? How long do the body and extremities of a bone continue unsolidified?

deposition of layers of bone upon the outside, similar to the successive rings of growth in a tree;[6] but their increase in length is by a different process. The ends of a bone are so much larger than the middle, and so different in shape, that the bone would be deformed if its elongation took place by deposition upon the ends. There is therefore a special provision for growth in this direction. A long bone has, at least, three centres of ossification: one for the formation of each extremity, and one for the formation of the body of the bone. So long as the bones are capable of elongating, the extremities of the bone are always separated from the body of it by sections of cartilage, as at *a a*, Fig. 3, and the bone increases in length by the deposition of bone at the ends of the body, thus pushing the extremities farther from each other. As soon as the body has fully acquired its growth, this section of cartilage becomes ossified.[7]

Fig. 3.



Bone of the arm. 1 1 Body of the bone. 2 2 The extremities (epiphyses) *a a* Layers of cartilage, by which the body and epiphyses are connected.

11. A dense, tough membrane, called the **periosteum** (bone envelope), surrounds the bones, except at their extremities. It serves to protect the bone, to supply it with its nerves and blood-vessels, and is the means by which the ligaments, tendons, and muscles are attached.[8]

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[6] The experiment in the preceding note was varied by feeding an animal that was growing rapidly with madder, for a few days, and then withholding it. The bone which was formed while the blood was charged with the coloring substance, would be more highly tinged than the bone previously

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11. What is the periosteum? What purposes does it serve? Into what four classes are the bones divided?

The bones are divided into four classes: those of the head, those of the trunk, and those of the upper and of the lower extremities.

Section II.—Bones of the Head.

THE bones of the head include those of the cranium and those of the face.

I. *Bones of the cranium.*

12. The bones of the cranium are composed of external and internal plates, and an intervening porous portion, answering to the hollow and the porous structure in the long bones, called the *diploë*. The external plate has the

---

formed would become by deposition of coloring matter into the interstices. The bones of the animal were found, upon examination, to consist of concentric laminæ of more highly and less highly colored bone, showing that the bone was formed by successive depositions upon the outside.

[7] If too much or too severe labor be required of an individual while these cartilages remain, and the body is forming, nature attempts to secure the system against injury by a more rapid ossification of them than would otherwise take place. Thus they may become bone before the body has acquired its full development. But it is impossible that any further growth of body should take place, and a dwarfed stature is the result. There are, however, other causes of such a stature. It may result from *too little exercise* in early life, or from disease, or it may be hereditary.

[8] This membrane, though ordinarily possessing but little sensibility, is sometimes subject to inflammation, when it becomes intensely painful The felon and fever sore are diseases originating in this membrane. Disease seldom attacks the bones directly; but it may be communicated to them either from the periosteum, or from the investing cartilage where this membrane is wanting, as in the joints.

Section II.—What do the bones of the head include? Name the bones of the cranium.

12. Of what three parts do the cranial bones consist? Describe each part.

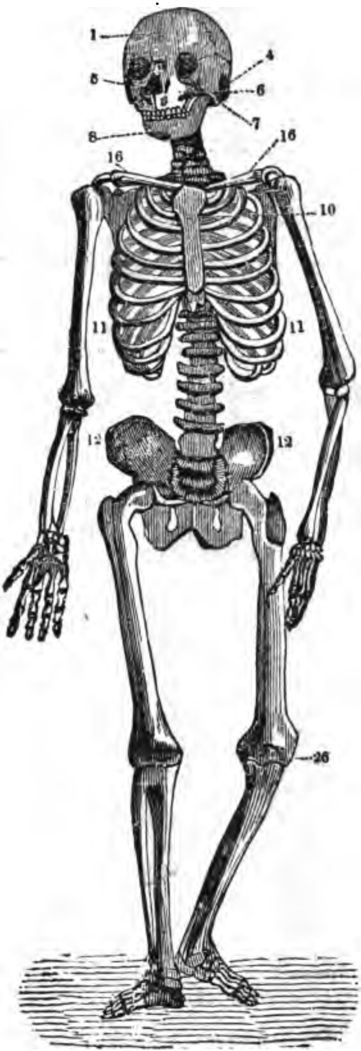


Fig.

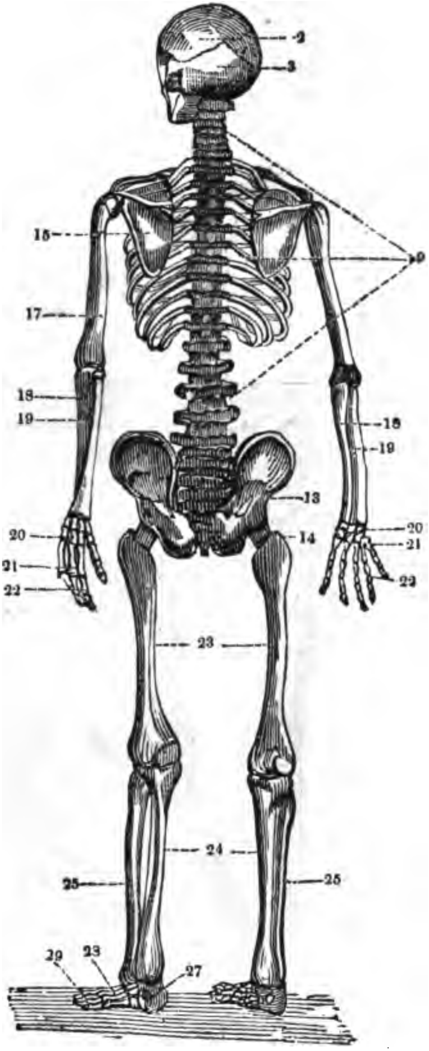
The Skeleton consists of 201 bones. In this enumeration the teeth, the hyoid bone, and the bones of the ear are not included. Certain bones in the sutures of the head, and in some of the joints, which, though generally present, are not regarded as essential parts of the framework, are also omitted.

NAMES AND CLASSIFICATION OF THE BONES.

1.	The frontal bone, . .	1	Bones of the Cranium 8.
2.	The parietal bones, .	2	
3.	The occipital bone, .	1	
4.	The temporal bones, .	2	
	The sphenoid bone, .	1	
	The ethmoid bone, .	1	
5.	The nasal bones, . .	2	Bones of the Face 14.
	The lachrymal bones,	2	
6.	The upper maxillary bones, ...	2	
7.	The malar bones, . .	2	
	The palatine bones, .	2	
	The lower spongy bones, ...	2	
	The vomer, ...	1	
8.	The lower maxillary bone, ...	1	

Fig. 5.

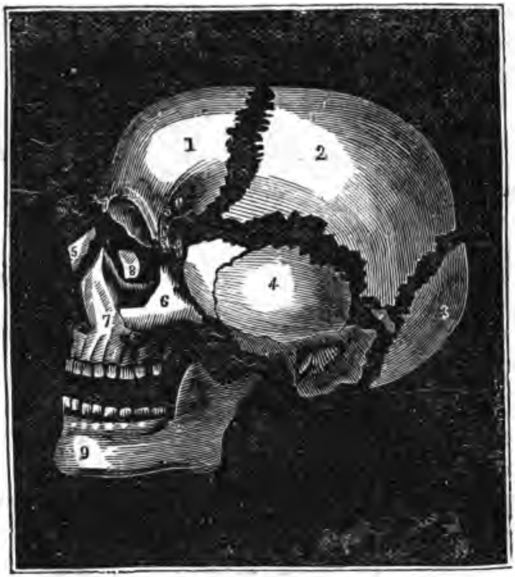
9. The vertebræ,	24	Bones of the Trunk 55.
10. The sternum,	3	
11. The ribs,	24	
12. The ossa innominata,	2	
13. The sacrum,	1	
14. The coccyx,	1	
15. The scapula,	2	Bones of the Upper Extremities 64.
16. The clavicle,	2	
17. The humerus,	2	
18. The ulna,	2	
19. The radius,	2	
20. The carpal bones,	16	
21. The metacarpal bones,	10	
22. The phalanges,	28	
23. The femur,	2	Bones of the Lower Extremities 60.
24. The tibia,	2	
25. The fibula,	2	
26. The patella,	2	
27. The tarsal bones,	14	
28. The metatarsal bones,	10	
29. The phalanges,	28	



toughness and hardness of ordinary bone; the internal, called the vitreous plate, is much harder. The bones of the cranium are eight in number.

13. The frontal bone (1, Fig. 6; 1, 1, Fig. 7) occupies the region of the forehead, and extends from the top of the head forward to the eyes and nose, and laterally about half-way to the ears. On the forehead, the two plates of the bone are considerably separated from each other, leaving the cavities above the eyes called the *frontal sinuses.* The external plate terminates at the ridge upon which the eyebrows are situated, while the internal plate

Fig. 6.



Bones of the Cranium, separated. 1 The Frontal bone. 2 The Parietal bone. 3 Occipital bone. 4 The Temporal bone. 5 The Nasal bone. 6 The Malar bone.

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13. What is the situation of the frontal bone? How are the frontal sinuses formed? Of what does the orbital plate consist, and how is it situated?

turns backward, forming the upper part of the orbit of the eye. This is the *orbital plate* of the frontal bone, and becomes the floor upon which the front lobe of the brain rests.

14. **The parietal bones** (2, Fig. 6) are two square, smooth bones, situated directly back of the frontal bone, united together at the top of the head, and forming the highest and the lateral portions of the cranium.

15. **The occipital bone** (Fig. 8; also 3, Fig. 6) forms, as the name indicates, the back part of the cranium, as well as the floor on which the posterior lobe of the brain rests. In the base of the bone is a large aperture, the *magnum foramen*, through which the spinal cord is connected with the brain. On the under margin of this foramen are two prominences, called *condyles* (button-shaped elevations), which contribute to form the joint between the head and spine.

16. **The temporal bones** (4, Fig. 6) are two irregularly shaped bones reaching downward from the parietal so far as to contain the cavity of the ear, then inward to within an inch of each other. Above the ear they are very thin. The portion which forms part of the base of the cranium, and within which the principal parts of the organ of hearing are situated, is called the petrous (stone-like) portion, and is very thick and hard.

They have three well marked processes: **the mastoid process** (1, Fig. 9), situated just back of the ear; **the styloid process** (2), a long, slender projection, near the mastoid, reaching down the side of the neck; and **the zygomatic process** (3), which rises forward of the ear, passes over the temporal muscle (4), and connects with

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14. Describe the parietal bones. Why are they called parietal?

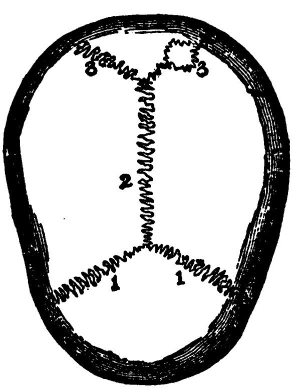
15. What is the meaning of occipital? How is the occipital bone situated? What foramen is found in it? Where and for what purpose are the condyles?

16. Describe the temporal bone. Its processes.

another process of the same name from the cheek-bone. Between the styloid and mastoid processes is a small opening in the bone (9), called the *stylo-mastoid foramen.*

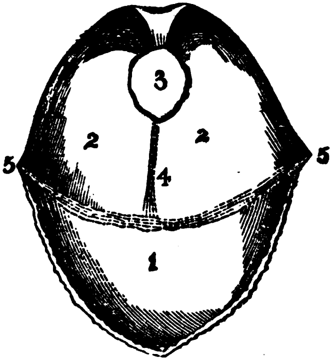
17. **The sphenoid bone.** (Fig. 10.) This is a bone of a very irregular shape, and has, with some degree of propriety, been compared to a bat with its wings extended. The body (1) is situated in the centre of the base of the cranium. Large processes (2, 2), called **the great wings,** extend up so far as to articulate (at 3, 3) with the frontal bone. There are two *pterygoid processes* (4, 4) on each side, reaching downward from the body of the bone, and situated directly back of the throat. They support the pharynx, and give attachment to several muscles of the neck.

Fig. 7.



The Cranium as seen from above. 1, 1 The Coronal Suture. 2 The Sagittal Suture. 3, 3 The Lambdoidal Suture.

Fig. 8.



The Occipital Bone. 1 The vertical portion, forming the back part of the Cranium. 2, 2 The horizontal portion, on which the back part of the brain rests. 3 The Magnum Foramen. 4 The ridge on the inner side of the bone, to which the Falx Cerebelli is attached. 5, 5 The ridge to which Tentorium is attached.

18. **The ethmoid bone** (sieve-like) has a nearly cu-

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17. Describe the sphenoid bone. **18.** Describe the ethmoid bone.

bical form, and is situated between the orbits of the eyes, directly in front of the body of the sphenoid bone. The upper plate is riddled with holes, which give passage to the branches of the olfactory nerves, and the lower portion is cellular, reaches down into the nose, and is an important part of the organ of smell.

19. The cranium, consisting of the eight bones which have now been described, has an ovoid form, flattened at the sides, and with the larger extremity backward. (Fig. 7.) In the base there are on each side three depressions, called the anterior, middle, and posterior *fossæ*.

20. The head of an adult person seems to consist of but one bone. In early life, however, the eight bones are not only distinct, but they are separated by a considerable width of cartilage (as seen, though with some exaggeration, in Fig. 6). The portion of cartilage which covers the soft spot on the top of the child's head, remains unossified for several years. This intervening cartilage, like that which separates the body and epiphyses of the long bones, is designed to provide for the growth of the cranium, as the inclosed brain requires increase of size. When the growth of the brain is completed, the ragged edges of the contiguous bones nearly touch, and the projecting fibres interlock (as represented in Fig. 7) in such a way as to make an immovable and very firm joint, called a *suture*. Yet the bones do not then come into actual contact; there is still an interposed layer of cartilage till after the meridian of life, when the cartilage begins to ossify, and the several bones of the cranium are at length consolidated into one. **The coronal suture** (1, 1) separates the parietal bones from the frontal bone; **the lambdoidal suture** (3, 3) sepa-

---

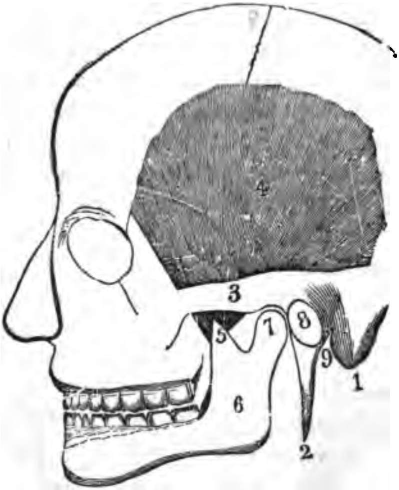
19 What is the form of the cranium? Describe the base.

20. What is a suture? Why are not the bones joined firmly together in early life? When do the sutures become obliterated? Name the principal sutures, and give their position.

rates the parietal bones from the occipital bone. **The sagittal suture** (2) separates the parietal bones. **The squamous sutures** separate each temporal bone from the adjacent parietal bone.[*]

21. Various parts of the system are designed, more or

Fig. 9.



1 The Mastoid Process. 2 The Styloid Process. 3 The Zygomatic Process. 4 The Temporal Muscle, passing under the Zygomatic Process, and inserted into the Coronoid Process, 5. of the lower maxillary bone. 7 The Condyloid Process of the lower maxillary. 8 The Ear. 9 the Stylo-mastoid Foramen.

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[*] There are several other sutures in the cranium, but they are not easily described without a skeleton.

The coronal suture is so named "from being near the part upon which the victor's crown (*corona*) was placed, in the games of the ancients;" the lambdoidal, from its resemblance in form to the Greek letter *lambda;* the "sagittal, from its direction backward, straight as a dart" (*sagitta*, an arrow); the squamous (*squama*, scale), from the scale-like overlapping of the temporal upon the parietal bone.

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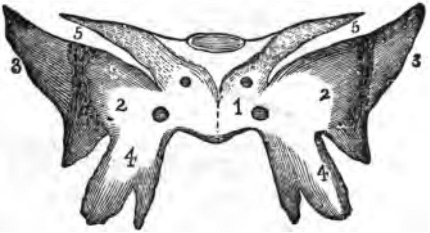
21. Name the four ways in which the cranium protects the brain against less directly, to *protect the brain*, but the cranium has this as its special object. The brain is a soft, yielding mass, and would be easily broken down and destroyed if it were not well protected. The substance of which the cranium consists, furnishes, by its hardness, a better protection than any other tissue would. The back of the head is most exposed to injury, either from accident or from malicious design, and accordingly the cranium has here the greatest thickness, while the sides of the head, which, in consequence of the position of the arms and shoulders, could scarcely receive any injury, are so thin as to be almost transparent. The arched form of the head enables it to resist the effect of blows more successfully than any other form. Pressure upon the top of the head would cause it to yield first at the sides, and this is prevented by the temporal bones coming up outside of the parietal, forming the squamous suture.

Fig. 10.



The Sphenoid Bone. 1 The body. 2, 3 The wings. 4, 4 The Pterygoid Processes. 5, 5 The superior Foramen Lacerum.

But violent jars and concussions are more likely to be permanently injurious than wounding the brain, or even

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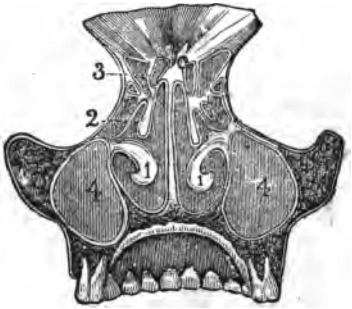
wounds. In what other way may the brain be injured? How are concussions absorbed before reaching the bone? How in passing through the bone? How is their continuance around the head prevented? How many bones compose the face?

removing portions of it. The cranium is well fitted to furnish protection in this respect also. It is covered with hair, with the general integument of the body, with muscles over a portion of its surface, and with the periosteum, through all of which the violence of concussions must extend before the outer plate of the cranium is reached. Then, between the external and internal plates, is interposed an elastic cushion, the diploë, by which concussions upon the outer plate will be partially absorbed before reaching the inner plate. Vibrations communicated to any one bone are prevented from continuing around the head by the cartilages interposed at the sutures.[10]

II. Bones of the face.

The face is composed of fourteen bones, two of which are single, the other twelve are in pairs.

Fig. 11.



A vertical section of the bones of the face, a little forward of the ears. 1, 1 Lower spongy bones. 2, 2 The middle spongy bones. 3, 3 Superior spongy bones. 4 Antrum Maxillare.

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[10] The cranium presents a fine instance of the adaptation of the system to the circumstances in which it is placed at the different periods of life.

In early infancy the cartilages are so wide and flexible that the form of the head may be considerably changed without injury, a fact upon which, at certain crises, the continuance of life often depends.

22. The nasal bones (5, Fig. 6) form the upper part of the nose, and articulate with the frontal and upper maxillary bones.

23. The lachrymal bones (8, Fig. 6) are situated in the orbits of the eyes, near the internal angle. They contain grooves for the passage of the lachrymal ducts, from which the bones receive their name.

24. The upper maxillary bones (7, Fig. 6) form a large part of the mouth and face. They inclose the large space on each side between the orbit of the eye and the roof of the mouth (4, 4, Fig. 11), called the *antrum max-*

Children are constantly receiving falls, blows, and thumps, in consequence of the incautiousness and recklessness natural to that period of life, which would be unsafe at a later period, but which seldom injure the brain, because the cranium is yet in so yielding a state as to absorb the motions which they impart. But while nature has thus interposed to protect the child, in a great measure, from the evils which his inconsiderateness would otherwise bring upon him, there is still a certain amount of care required on his part. The various plays, such as *ball*, *goal*, etc., which combine amusement and exercise, are therefore greatly preferable to *tricks*, *summersets*, *wrestling*, etc.

In manhood, the cranium remains in part cartilaginous, not so much so as to unfit one for the vigorous activities of life, and yet so far so as to interpose something of security against accidents. This security is much less, however, than it was in childhood; because a greater degree of carefulness and forethought has rendered such security less necessary.

In advanced life, the cartilages all become ossified; but at this period of life, also, severer labors are laid aside, and cautiousness of character begins to predominate, so that the brain needs fewer safeguards.

This is probably a reason why aged persons are often so averse to noise, to the prattle of children, etc. It may be peevishness, second childhood. It may, often probably does, arise from those physical changes in the structure of the cranium, by which the brain is affected sensibly, perhaps painfully, by the vibrations of the air.

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22. Describe the nasal bone.

23. The lachrymal bone. Why is it so named?

24. Describe the upper maxillary bone. Where is the antrum maxillare situated? Name and describe the five processes of this bone.

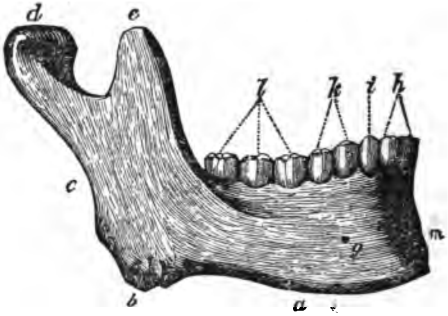
illare. These bones have several processes. The nasal process passes up along the side of the nose to the frontal bone; the orbitar process forms the base of the orbit of the eye; the malar process articulates with the malar bone; the palatine process forms the fore part of the roof of the mouth; the alveolar process is the projection in which the teeth are imbedded.

25. The malar bones (6, Fig. 6) are the large square bones which form the prominences of the cheeks; they also form part of the orbit of the eye.

26. The palatine bones form the back part of the roof of the mouth. Processes extend up from these bones into the nose, and form part of the organ of smelling.

27. The lower spongy bones (1, 1, Fig. 11) consist each of a very thin plate, which lies rolled up, and is attached to the side of the antrum maxillare.

Fig. 12.



The Lower Jaw. *d* The Condyloid Process. *e* The Coronoid Process.

28. The vomer is the thin flat bone that divides the nostrils from each other.

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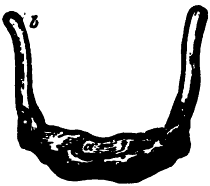
25. The malar bone.
26. The palatine bone.
27. The lower spongy bone.
28. The vomer.

29. The lower maxillary bone (9, Fig. 6) forms the lower jaw. It has three processes: the alveolar process, in which the teeth are set; the coronoid process, which is the sharp point at the extremity of the bone (*e*, Fig. 12) for the insertion of the temporal muscle; and the condyloid process (*d*), by which the lower jaw articulates with the temporal bone.

30. There is one other bone, **the os hyoides** (Fig. 13), which, though not one of the bones of the face, may be described with them. The front part of this bone (*a*), called the body, is at the root of the tongue. The two processes (*b*), called its cornua, reach back on the sides of the tubes which communicate with the stomach and lungs. This bone is the centre of all the motions of the throat and tongue.

Fig. 13.



The Hyoid bone. *a* The body. *b* The Cornua.

Section III.—Bones of the Trunk.

They are the bones of the spine, of the thorax, and of the pelvis.

I. *Bones of the spine.*

31. The spine (Fig. 14) is a nearly vertical column, consisting of the sacrum (4, 5) as its base, upon which are piled twenty-four bones, called vertebræ, and below which is the small terminal bone (5, 6), called the coccyx. The

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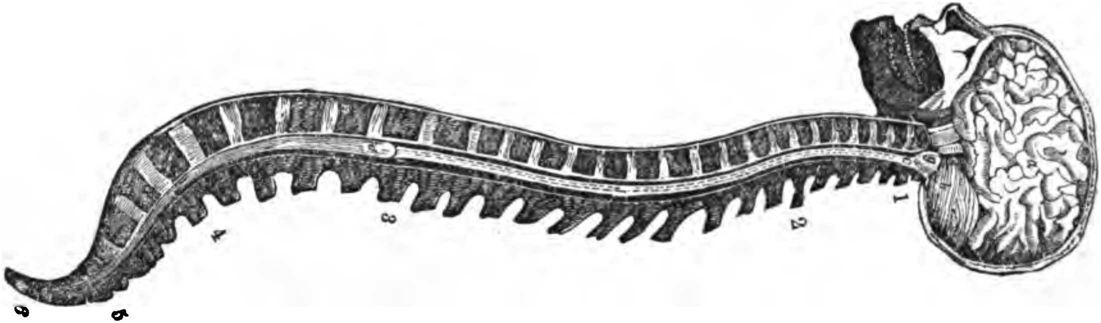
29. The lower maxillary bone. Describe its processes.

30. What other bone is described? How is it situated, and what is its use?

Section III.—How are the bones of the trunk divided?

31. Describe the spine. Into what three classes are the vertebræ divided, and how is each class situated?

Fig. 14.

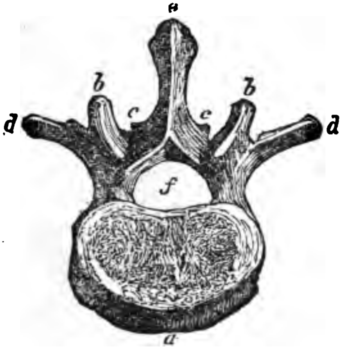


The Spinal Column. 1. 2 Cervical vertebræ. 2. 3 Dorsal vertebræ. 3. 4 Lumbar vertebræ. 4. 5 The Sacrum. 5, 6 The Coccyx: there are often several coccygeal bones.

seven highest vertebræ (from 1 to 2) are in the neck, and are hence called cervical vertebræ; twelve are in the back (from 2 to 3), and are called dorsal vertebræ; and the remaining five (from 3 to 4) are in the loins, and are called lumbar vertebræ.

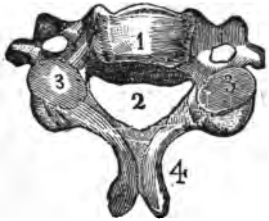
32. A vertebra (Fig. 15) is composed of a body and seven processes. The body (*a*) is the front part of the vertebra, of cylindrical form, and of spongy texture, having its upper and lower bases nearly flat, and composed of more solid bone. The processes are situated on the back part of the body of the vertebra. There are four oblique processes (*b b*), (sometimes called articulating processes), one above and one below, on each side. The transverse processes (*d d*), one on each side, project laterally from between the oblique processes. The spinous process (*e*) projects from the middle of the bone backward.

Fig. 15.



a The body of a Vertebra. *e* The spinous process. *d d* The transverse processes. *b b* The oblique processes. *f* The spinal canal.

Fig. 16.



The body of a Cervical Vertebra. 2 The canal. 3, 3 The oblique processes. 4 The spinous process with its cleft extremity.

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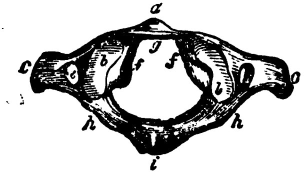
32. Of what is a vertebra composed? Describe the body of a vertebra. Where are the processes situated? How many kinds are there? Give the position of the oblique; the transverse; the spinous.

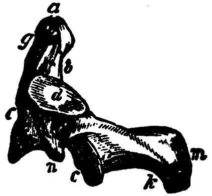
33. The vertebræ, in different parts of the spinal column, present great differences of form. The bodies of the cervical vertebræ (Fig. 16) are small, and so articulated as to allow great freedom of motion. **The atlas** (Fig. 17) is the first cervical vertebra. There are two faces (*b b*) on the upper side, adapted to the condyles of the occipital bone of the cranium; these constitute the joint which allows the vertical, nodding motion of the head. The processes, with the exception of the transverse, are scarcely developed. It has, properly, no body; but, in its place, there is a hole (*g*)—or rather, an enlargement of the spinal canal, and separated from it by a strong ligament—for the reception of a process from the next vertebra below.

Fig. 17.



The Atlas. *b b* The depressions for receiving the condyles of the occipital bone. *c c* The transverse processes. Between *f* and *f* is a strong ligament by which the dentatus is prevented from pressing upon the spinal marrow.

Fig. 18.



The Axis. *a* The dentatus, a prolongation of the body upward through the hole *g*, in the Atlas, Fig. 17.

The second vertebra of the neck is called **the axis.** The body of this vertebra is prolonged upward into a tooth-like projection (*a*, Fig. 18), called the dentatus, which is fitted to the corresponding opening (*g*) in the

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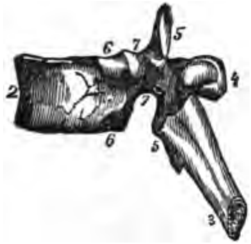
33. What is the peculiarity of the cervical portion of the spine? Describe the atlas; the axis. What is the peculiarity of the dorsal portion? What of the lumbar vertebræ? What is the arrangement of the oblique processes of the lumbar vertebræ? Why is any special protection necessary in this part of the spine? In what does this protection consist? What part of the spine is most liable to injury?

atlas, and becomes the pivot on which the horizontal motions of the head are performed.

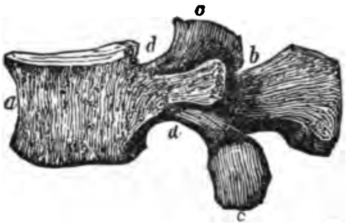
The dorsal vertebræ (Fig. 19) are larger than the cervical, and the oblique processes are so arranged as to allow of but little motion in this part of the spine. The spinous processes also, which are very long, project downward upon the next vertebræ, so as to bind them together, and limit their motions to a very small amount.

Fig. 19.



A Dorsal Vertebra. 2 The body. 7, 7 The notches to form the intervertebral foramina. 3 The spinous process, very long and very much inclined.

Fig. 20.



A Lumbar Vertebra. *a* The body. *b* The spinous process, *c c* The articulating (oblique) processes. *d d* The intervertebral notches.

The lumbar vertebræ (Fig. 20) are the largest in the spine. The upper oblique processes (*c*) form two pillars, between which are fitted so deeply the lower oblique processes from the next vertebra above, that dislocation is impossible without violence sufficient to break the processes. In this part, the spine, which has to support most of the weight of the body, is not assisted by any other part of the skeleton, and very free motion being required, every possible means is resorted to, to increase its strength, by increasing the size of the vertebræ, by binding them together with ligaments, by interlocking their oblique processes, and by attaching muscles, which act as stay-ropes, to the projecting spinous and transverse processes. Still, this is the least protected part of the spine, and most frequently suffers injury.

34. The faces of the adjacent vertebræ do not come into actual contact, but are separated by the intervention of an elastic substance (2, Fig. 21) resembling *cartilage.*

35. The notches in the vertebræ, as seen at 7, Fig. 19, form, when the vertebræ are placed together, the openings, as seen at 1, Fig. 21, called the **intervertebral foramina,** through which the spinal nerves pass out from the spinal cord.

36. The processes are so arranged that a tube (*f,* Fig. 15) passes through each vertebra, and as the bones are placed one upon another, these tubes become continuous through the spinal column, and form the **spinal canal** (*c d,* Fig. 14), in which the spinal cord is lodged.

37. The spine serves several distinct *purposes.* In the first place, it is the framework, **the axis of support** of

Fig. 21.

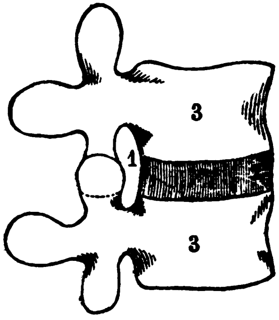


Fig. 22.

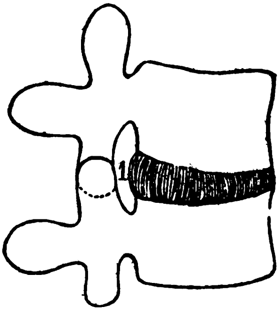


Fig. 21. Two Vertebræ 3 3. 2 The intervertebral substance between them. 1 The intervertebral foramen. Fig. 22. Two Vertebræ, with the form of the intervening cartilage produced by bending the spine.

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34. By what are the vertebræ separated?
35. How are the intervertebral foramina formed? What is their use?
36. How is the spinal canal formed? What is its object?
37. What is the first purpose which the vertebral column serves? What is the

the trunk.[11] For this purpose, great firmness is required, the general provisions for which have been referred to in describing the lumbar vertebræ.

In the second place it must be so constructed as to allow great *freedom of motion.* The provision for bending the body backward, forward, and to either side, consists in the elasticity of the intervertebral cartilages. Each cartilage is firmly attached to the faces of the vertebræ between which it is placed, so that motion (excepting in the upper two joints) is not performed by the surfaces sliding upon each other, but by the compression of the cartilage on the other side (2, Fig. 22) toward which the flexion is made, and the slight thickening (1) of the same cartilage on the opposite side. The number of the joints is so great that the necessary flexibility is secured, while only a slight motion at any one joint is required. When the body is turned horizontally without changing the position of the pelvis, the motion is performed by a slight twisting of the cartilages; but this kind of motion is very limited.[12]

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[11] It should not, however, be considered that the support which the head and trunk require is derived wholly from the firmness of the spine. The spine follows the back side of the trunk, and on the front side there is a succession of muscles from the neck to the pelvis. As the spine would prevent an undue bending of the trunk forward, so these muscles will not so far yield as to allow of an undue bending of the trunk backward.

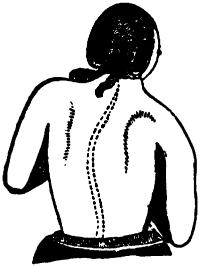
Moreover, as the whole space within the walls of the chest and abdomen is always filled, the trunk is, to a considerable extent, self-supporting; upon the same principle that a bag filled with grain will stand erect and support heavy weights in addition, though neither the grain alone nor the cloth alone, would retain such a position.

[12] There is an obvious tendency of the cartilages to resume their natural form when they have been pressed out of it; but they do not do it at once. A person's height is diminished during the day by continuous pressure upon

second? How are the motions of flexion performed? How is horizontal motion performed? What is the third object of the spinal column? What are the liabilities to be provided against? What is the security against compression of the

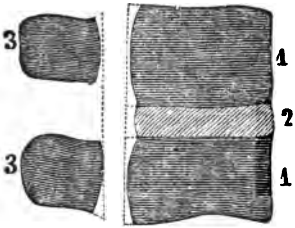
In the third place, it must be so constructed as to furnish a *passage for the spinal cord,* which shall secure it against injury both from without and from the motions of the spine. So large a proportion of the spine consists of bone, that the walls of the canal will resist any compres-

Fig. 23.



Distorted Spine produced by habitual elevation of one shoulder.

Fig. 24.



1, 1 Two vertebræ. 3. 3 The corresponding spinous processes. 2 The intervertebral cartilage.

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the cartilages. It is recovered, however, during the night. But if they be thus pressed habitually, they do not readily react; and there is danger that they will at length cease to react at all. A constrained position thus habitually assumed is liable to produce a permanently distorted spine. Persons engaged in any employment which requires the spine to be thus bent, should assume the erect or opposite position as frequently as possible.

Persons often raise one shoulder (generally the right shoulder) habitually higher than the other. The active employments of life often require it. Children at school, if the tables are too high, will sit with the side at the table, and one arm elevated upon it. This position may be rendered necessary by the employment chosen; but more frequently it becomes unnecessarily fixed as a habit, through inattention. A permanent inequality of the shoulders is thus produced, the spine becomes bent (Fig. 23) to adapt it to this position of the shoulders, and a corresponding change in the position of the internal organs, often leading to disease, will follow. Special attention is directed to this deformity, because it is contracted by a large proportion of persons who have reached mature life. And young persons, by careful attention, will be able to correct the tendency to it.

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spinal cord? What against fracture of the spinal column? What against injury

sion to which it is ever liable. The flexibility of the spine and the toughness of the cartilages render it much more secure against fracture than it would be if it consisted of solid bone. The only danger, then, to which the spinal cord could be exposed, must arise from the bending of the spine. The security here consists in that part of the canal which is formed of cartilages (2, Fig. 24) being larger than that formed by the bodies of the vertebræ (1, 1). Compression of the cartilages may cause them to bulge out beyond their natural position; but it will not be to such a degree as to make those portions of the canal smaller than the portions which are formed of bone.

In the fourth place, the spinal column affords considerable *protection to the brain* against the concussions which it would receive, if the head were connected with the lower extremities by an axis of solid bone. The jar occasioned by walking and by many active employments, as well as the more violent concussions occasioned by accidents, by running, jumping, leaping from great heights, etc., are, to a considerable extent, absorbed by the compression of the intervening cartilages. But another and very important security against injury from these sources, is the curvature of the spine. By recurring to Fig. 14, it will be seen that there is a forward curve in the loins, and one in the neck, and these being the most flexible parts of the spine, easily allow an increased bending for a moment, whenever any of these concussions occur. Such bending would not take place in a straight column, and whatever force is necessary to produce it, would, without those curvatures, be so much additional concussion upon the brain.

II. *Bones of the thorax* (Fig. 25).

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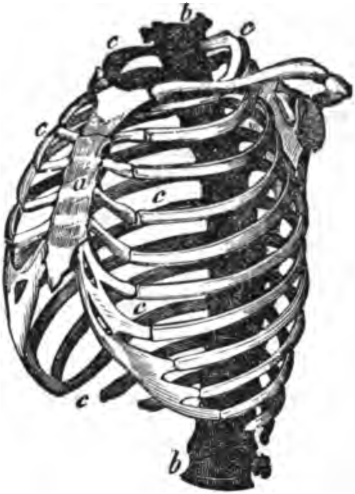
to the spinal cord, by the flexion of the spinal column? What is the fourth object of the spinal column? What does it protect the brain against? How do the cartilages furnish this protection? How do the curvatures?

They are the sternum and the ribs.

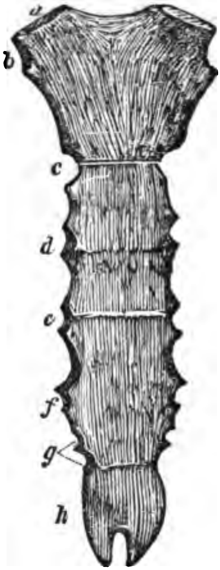
38. The sternum (Fig. 26) is the flat bone situated on the front side of the thorax. It is about eight inches in length, and consists of three pieces, of which the lower one is cartilaginous, except in very old age. Its object is to provide for the joining of the ribs, and to protect the cavity of the thorax from compression.

Fig. 25.



The Thorax. *b b* The Spine. *a* The Sternum.

Fig. 26.



The Sternum. From *c* to *g* is the middle portion of bone. The apparent separation at *d* and *e* do not indicate separate bones.

39. The ribs (Fig. 27) are the twenty-four slender

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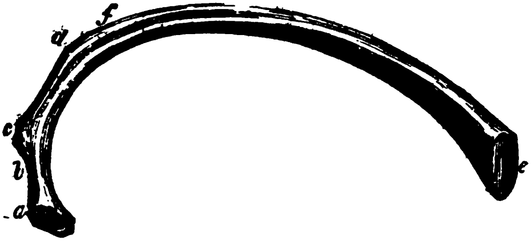
38. Describe the sternum. What is its use?

39. Describe the ribs. How are the true and false ribs distinguished?

bones which protect the sides of the thorax. They extend from the spine around the body toward the sternum, and are lengthened out by cartilage to their sternal articulation. The upper seven on each side articulate with the sternum by separate cartilages, and are called true ribs. The remaining five have their cartilages united into one, and are called false ribs. Frequently, however, the lowest rib, and sometimes the lowest two ribs, are not connected to the sternum by cartilage, and are called floating ribs. The posterior end of each rib is fitted to a slight cavity in the corresponding vertebra, and is also attached by a distinct joint to the end of the corresponding transverse process. The ribs are considerably inclined, so that the anterior articulation is lower than the posterior.

Fig. 27.



One of the Ribs. *a* Articulation with the vertebra. *c* Articulation with the Transverse Processes.

40. One **object** of the bones of the thorax is the protection of the heart and lungs, the organs which they surround.

But they have another object more indispensable, that of forming a cavity the size of which is not dependent upon the organs which it contains. The abdomen is another

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40. What are the objects of the bones of the thorax? How does the cavity of the thorax differ from that of the abdomen? Upon what does the process of respiration depend? Of what is the pelvis composed?

closed cavity, similar in many respects to the thorax, but, being surrounded only by muscles and membranes, it enlarges and contracts as the organs within it are more or less distended. The thorax, on the contrary, having its general form determined by a framework of bone, cannot contract beyond a certain amount, however much the organs within may become reduced, and it is capable of enlargement independently of the dimensions of the organs within.

It is the power of enlarging and contracting this cavity at pleasure upon which the process of respiration depends.[13] When it is enlarged the air enters the lungs, and they increase in size so as to keep the cavity filled. The effort to contract the thorax compels a portion of the air to escape. This ingress and egress of the air is respiration; but there are important chemical changes effected by it which, as well as the muscular apparatus by which it is performed, will be explained in connection with the description of the lungs.[14]

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[13] It will be shown, in the chapter on the circulation, that the motion of the blood in the veins is also in a great measure dependent upon these changes in the dimensions of the thorax.

[14] This is not the proper place to consider fully the effects of certain habits of dress upon the function of respiration. There is no question but that the form may be to a great extent controlled by dress. The thorax, which, if allowed to take its natural form, would be represented by Fig. 28, may, by compression, be so reduced as to be correctly represented by Fig. 29.

And the effects of this compression upon health and the duration of life are necessarily considerable. The greatly reduced capacity of the chest is itself of the nature of disease, and it contributes more perhaps than any other habit to invite other diseases, particularly those of a pulmonary character, but also the whole train of dyspeptic and nervous diseases.

But the influence of habit is not easily counteracted by exhibiting its consequences. A slender waist is regarded as graceful, and so long as it is so regarded, it will be sought even at the expense of health. If a taste

III. *Bones of the Pelvis.*

The Pelvis is composed of the ossa innominata, the sacrum, and the coccyx.

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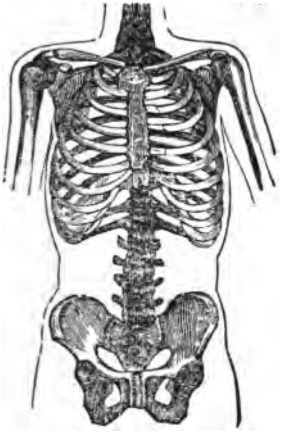
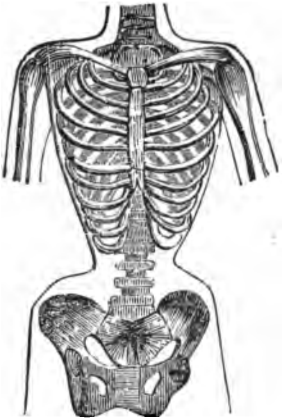
for more active employment could be cultivated, it would control this fashion, by rendering so much compression unendurable. Let habits of productive industry be formed by those to whom the avails of it would not be a motive. Such habits are important, not simply from the possibility that they may come into requisition by reverses of fortune, but specially so, in consequence of the influence which they would have in giving a proper development to the physical as well as mental and moral system. But if these are to be discarded, the only substitute for them, so far as a healthy physical development is concerned, is to require a large amount of active out-of-door life, such as travelling, walking long distances in the open air, riding on horseback, etc. Such active habits, whether they be those of amusement or of productive industry, require a large supply of air in respiration, and it will be natural and almost necessary to adapt the dress to this demand.

Fig. 28.



A fully developed Chest.

Fig. 29.

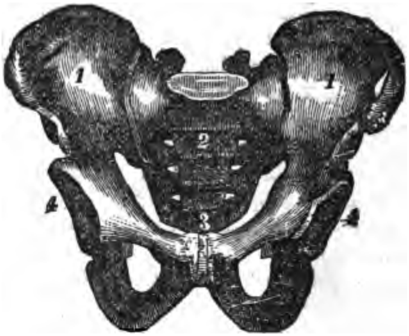


Chest contracted by compression.

Still, since this habit of compressing the thorax prevails to such an extent, it is proper to remark that other habits of cultivated society, how-

41. The sacrum and coccyx have before been referred to as forming the lower part of the spine. They also constitute the back part of the pelvis (2 and 3, Fig. 30).

Fig. 30.



The Pelvis. 1 The ilium. 2 The sacrum. 3 The coccyx. 4 The acetabulum.

ever objectionable they may be in themselves, are, to some extent, compensatory of the evils of tight dressing. The capacity of the thorax—that is, the amount of respiration—which would be necessary in one state of society, would be altogether unnecessary in another. The habits of women in the most refined society of the age when the Venus de Medici was the *beau ideal* of female form, were such as to require a much fuller development of the thorax than would be required by the habits prevailing in the corresponding ranks of society at the present time. A lady, whose severest employments are embroidery and romance reading, requires but little air in respiration, and therefore only a small chest.

Also, the different pursuits and conditions of men render the amount of air required very different. An insufficient amount of clothing, exposure to severe and long continued cold, and the most active physical labor, require of the sailor, of the hunter, of the backwoodsman, and even of the farmer and the laborer in many mechanical employments, such a development of the thorax, and such an amount of air in respiration, as would be not only unnecessary but hurtful to the laborer in the more sedentary mechanical employments, to the student, the clerk, the merchant, and the professional man.

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41. Why are the sacrum and coccyx mentioned in this connection?

42. **The ossa innominata** (bones without a name, Fig. 30), are two irregularly-shaped bones, proceeding from the sacrum, one on each side and meeting in front. Each bone, from having been in the early stages of ossification in three pieces, is generally spoken of as three bones, the ilium, which is the upper part (1); the ischium, which is the lower part; and the pubis, which is the front part.

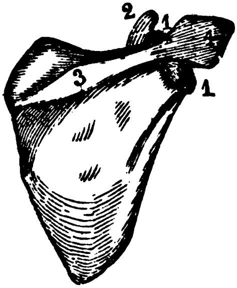
43. The pelvis furnishes the vertical support for the abdominal viscera. It also gives support to the spine, and hence to the head and trunk. The pelvis furnishes the means of attaching the lower extremities. For this purpose, it contains a large socket on each side (4, 4, Fig. 30), called the acetabulum. The ilium, ischium, and pubis, all unite at the centre of this socket, and contribute to form it.

Section IV.—Bones of the Upper Extremities.

They are the scapula, clavicle, bones of the arm, forearm, and hand.

44. **The scapula** (Fig. 31) is a broad, thin bone, of a triangular shape, and lies imbedded in the muscles of the back. Near its outer angle the bone becomes thick and terminates in a slightly concave surface (1, 1), called the glenoid cavity. The coracoid process (2) rises from the neck of this cavity and projects over it in front. The

Fig. 31.



The Scapula. 1, 1 The glenoid cavity. 2 The coracoid process. 3 The spine of the scapula. 4 The acromion.

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42. Describe the ossa innominata. Why have the three parts distinct names? What are the three parts, and how are they situated?

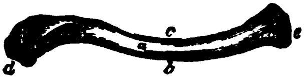
43. What are the three uses of the pelvis? How does it furnish the means of attaching the lower extremities?

Section IV.—What are the bones of the upper extremities?

44. Describe the scapula: the glenoid cavity; the two processes of the scapula. How is the socket for the shoulder joint formed?

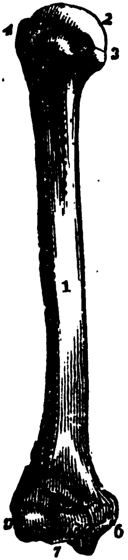
high ridge of bone (3) on the back of the scapula, is called the spine of the scapula. It terminates in a process (4), called the acromion (point of the shoulder), which reaches beyond the glenoid cavity on the back side. The socket for the shoulder joint, is formed by the glenoid cavity, raised at its edges by cartilage, and protected by the coracoid process and the acromion.

Fig. 32.



The Clavicle, e, its articulation with the sternum, d, its articulation with the shoulder.

Fig. 33.



The Humerus. 1 The Shaft. 2 The head fitted to the glenoid cavity. 5, 6 External and internal condyles.

Fig. 34.

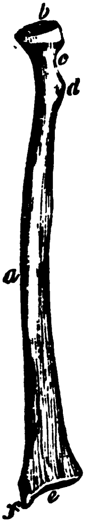
The Ulna. a The sigmoid cavity. b The coronoid process. e The olecranon.

45. The clavicle (Fig. 32, seen also in Fig. 25) extends from the upper extremity of the sternum, to the acromion of the scapula. Its use is to brace the scapula back, and prevent the shoulders from falling in toward each other, so as to restrict the motions of the arms.[15]

46. The humerus (Fig. 33) extends from the shoulder to the elbow. The upper extremity is received into the glenoid cavity to form the shoulder joint. The bone is nearly cylindrical except at the lower extremity, where it is flattened; and the corners of it (5 and 6), are the external and internal condyles. Between these condyles on the front side is a depression, called the lesser sigmoid cavity, and on the back side, directly opposite, is a similar depression called the greater sigmoid cavity.

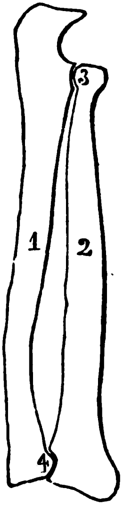
47. The bones of the fore arm are **the ulna** (Fig. 34), and **the radius**. They reach from the elbow to the wrist, and are nearly parallel. The upper extremity of the ulna, the point of the elbow (*e*) is **the olecranon**. A little lower on the front side of the ulna (*b*) is **the coronoid process**, and the sigmoid cavity of the ulna (*a*) is between these processes. This cavity receives the lower extremity of the humerus to form the elbow joint. When the elbow is bent to a sharp angle, the coronoid process falls into the lesser sigmoid cavity of the humerus and prevents any further flexion. In like manner, when the arm is straightened, the olecranon fits into the greater sigmoid cavity and checks the motion in that direction.

Fig. 35.



The Radius.

Fig. 36.



Bones of the fore arm. 1 The ulna. 2 The radius. 3, 4 The condyles, which, with the corresponding cavities, form the joint for the rolling motion of the hand.

The radius (Fig. 35), at its upper extremity, has a small protuberance (3, Fig. 36), which

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[15] The clavicle is fully developed only in the human species, though it is found in a rudimentary state in such other animals as the cat, squirrel, and monkey, which use the fore feet, to some extent, as hands. In those animals which use the anterior extremities only as organs of locomotion, motion is required in only one direction. These extremities are in such animals brought near together, and the clavicle is therefore entirely wanting.

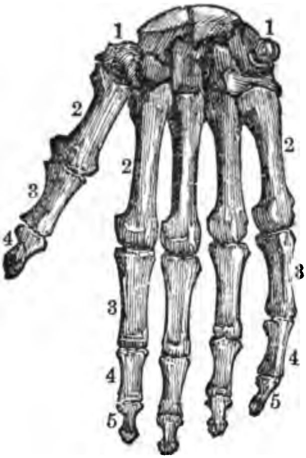
45. Describe the clavicle. What is its use?

46. Describe the humerus. Describe the condyles and cavities of its lower extremity.

47. What are the bones of the fore arm? How are they situated? How is the

is fitted to a slight depression in the ulna. In the same way the ulna is attached at its lower extremity (4) to the radius. The ulna, in consequence of the hinge joint at the elbow, can have no rolling motion, but the radius in consequence of this double joint (3 and 4) is capable of performing nearly half of a revolution, and as the wrist is not articulated with the ulna but with the radius, the rolling motion of the radius carries the hand with it. The motions of pronation and supination of the hand, depend therefore upon this double articulation of the radius and ulna.[16]

Fig. 37.



The Hand. 1, 1 The carpal bones. 2, 2 The metacarpal bones. 3, 3. 4, 4. 5, 5 Phalanges.

48. The bones of the Hand. The wrist is formed of eight carpal bones (1, 1, Fig. 37); the hand by five metacarpal bones (2, 2), and the thumb and fingers by the five bones in each of the first

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[16] The extent of motion of this kind of which any person's hand is susceptible is easily determined by trial. Expose the fore arm, and hold the elbow so that there shall be no motion of the humerus, then see how far the hand can be made to rotate. In young persons it will often be three quarters of a revolution; but the utmost possible amount should not often be attempted. The movement of the radius will be distinctly seen, though enveloped in muscle and integument.

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sigmoid cavity of the ulna formed, and what is its use? What are the processes above and below this cavity? What limits the motions of the elbow joint forward? How are they limited backward? Describe the articulations of the radius and ulna. What is the object of this mode of articulation? Why cannot the rolling motion of the hand be performed by the elbow joint?

48. Describe the bones of the hand.

and second phalanxes (3, 3 and 4, 4), and four bones (5, 5), in the third phalanx.

49. In the structure and use of the superior extremities, there is a broad anatomical distinction between man and the inferior animals. In all other animals, they are designed to be used, more or less, as organs of support and locomotion, and this use renders them less fitted for the special uses to which they are appropriated in man, that is, as organs of *touch* and *prehension*.

Their peculiar adaptation to these purposes consists in their length, in their slender form, in the freedom of motion of which they are capable at all the joints, particularly those of the shoulders, in the extent of pronation and supination of the hand, in the degree of separateness given to the fingers, in the position of the thumb, which is directly opposed to the fingers, in the muscular power of the thumb, which nearly equals that of all the fingers, and in the great delicacy of the sense of feeling in the hand, and particularly at the ends of the fingers.

Section V.—Bones of the Lower Extremities.

THESE are the femur, the tibia, the fibula, the patella, and the bones of the foot.

50. The femur (Fig. 38) has, at its upper extremity, three well marked prominences. The first is the highest

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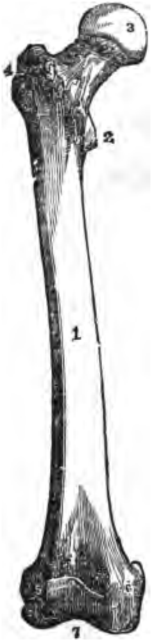
49. What distinction is mentioned between the anatomy of man and the inferior animals? What are the uses to which the upper extremities, in man, are principally subservient? To what uses are the corresponding organs put in other animals? Why must they be less perfect than in man as organs of prehension and touch? They are adapted to these purposes in man by peculiarities in eight respects; what are they?

Section V.—What are the bones of the lower extremities?

50. Describe the femur.

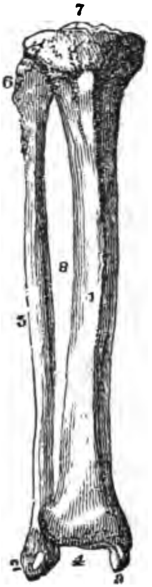
part of the shaft of the bone (4), and is called the trochanter major. The next is the head of the femur (3). It sets off from the axis of the femur about three inches on a neck of bone, and terminates by a spherical surface which is received into the acetabulum to form the hip joint The third eminence (2) is the trochanter minor, situated on the interior side of the femur below the neck. On the posterior face of this bone for about two thirds of its length, is a rough ridge called the linea aspera. The inferior extremity of the femur presents a large articulating surface for the knee joint. This surface (7) is divided behind by a deep groove into two portions, called the external and internal condyles (5 and 6).

Fig. 38.



The Femur. 1 The shaft. 2 The trochanter minor. 3 The head of the femur. 4 The trochanter major. 5. 6 External and internal condyles. 7 The articulating surface for the knee joint.

Fig. 39.



1 The Tibia. 5 The Fibula. 2, 3 The external and internal malleolus. 4. 7 Articulating surfaces.

51. The tibia and **fibula** (Fig. 39) are two parallel bones reaching from the knee to the ankle. The largest bone (1) is the tibia. Its upper extremity presents a large surface for the articulation at the knee. The lower extremity articulates with the astragalus (the central bone

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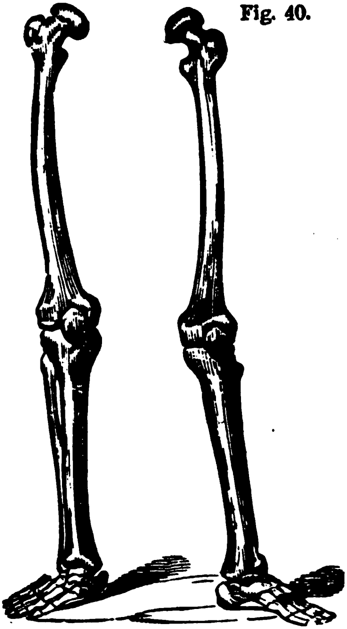
51. Describe the tibia. How is the ankle joint protected?

of the ankle) to form the ankle joint; and a process of the tibia (3), called the internal malleolus, extends down the side of the astragalus to protect the joint.

52. The fibula (5) articulates with the head of the tibia just below the knee joint, extends on the outside of the leg to the ankle joint, and terminates in the external malleolus (2) at the side of the astragalus.

53. The patella is a flat circular bone about two inches in diameter, situated in front of the knee joint (Fig. 40). As the knee joint is one of the most exposed in the system, this bone is placed over it to strengthen it. An ordinary tendon passing over this joint would also be liable to frequent injury, and we may regard the patella as only an ossified portion of the tendon which transmits over the joint the muscular power by which the knee is straightened.

Fig. 40.



The bones of the Lower Extremities.

54. Bones of the Foot. The ankle is formed by seven tarsal bones (*g*, *d*, Fig. 41), the foot, by five metatarsal bones (*a*), and the toes, by five bones in each of the first and second phalanges (*b*, and *c*), and four bones (*m*), in the last phalanx.

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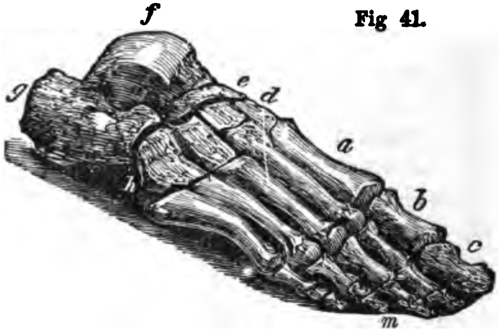
52. Describe the fibula.
53. Describe the patella. What are its uses?
54. What are the bones of the foot?

55. Since the body, in man, is to be *supported* on two extremities, instead of four, as in other animals, it is necessary that the foot should have certain peculiarities, fitting it for this office. These peculiarities are its length, the projection of the heel backward, and its articulation at right angles to the leg.

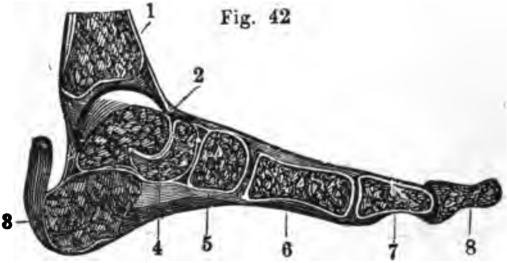
Fig 41.



Bones of the foot. *a*, The metacarpal bones. *b.c. m*, The phalanges. *f*, The astragalus. *g*, The os calcis.

Its adaptation to the required *motions*, those of walking, leaping, and running, consist principally in the great power of the muscle which is attached to the extremity of the heel (the os calcis, 3, Fig. 42), the length of this bone as a

Fig. 42



A vertical section of the Foot, lengthwise. 1 The tibia. 2 The astragalus. 3 The os calcis, with the tendon of the muscle attached. 4, 5 Bones of the foot. 6 A metatarsal bone. 7, 8 Phalanges. In this figure the arched form of the foot is well shown.

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55. What is the first office of the foot? What peculiarities fit it for this purpose? What is the second, and how is it fitted for it? What is the third use of

lever, and the power of varying very much the angle made by the leg and foot.

The motions of the body, would be injurious to the brain and vital organs, if there were no provision for absorbing them. Such concussions we experience by stepping only a few inches lower than we expect to, when walking in the dark. The principal means of deadening these shocks consist in the construction of the foot. In these motions, either the toe or heel, first receives the weight of the body, and the concussion is partially absorbed, before the other end of the foot is brought down. The arch of the foot, directly over which the ankle joint is placed, is then depressed. If too much of the concussion still remains, the knee and hip joints are then gradually bent, in order to receive it.

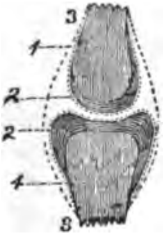
CHAPTER II.—OF THE ARTICULATIONS.

Section I.—Parts of which the Joints are composed.

56. A joint is formed by the contact of two articular faces of bone, together with several appendages for guarding it against dislocation, and for securing freedom of motion.

57. If the surfaces of bone were in direct contact, the requisite motions would rapidly wear them, and destroy the joint. To obviate this, a layer of *cartilage* (2, 2, Fig. 43) covers every articular surface. Thus, instead of bone, there are brought together two smooth surfaces of an elastic substance between which there is scarcely any friction.

Fig. 43



1, 1 Two bones connected by a joint. 2, 2 The cartilages by which the ends are covered. The synovial membrane, represented by the dotted lines, covers the cartilage, and extends back to 3, 3; then follows the capsule, which lies outside of the dotted line, and is not here represented.

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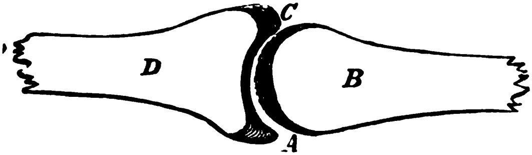
the foot? What are the means by which the foot absorbs the concussion produced by the motions of the body? What further provision exists for absorbing th

A cartilage which covers a convex articular surface is thickest in the middle (Fig. 44), and that which covers a concave surface is thickest around the edges. This elevated rim of cartilage in some of the joints, as that of the shoulder, constitutes the most important part of the sockets, so that cartilages become, to a considerable extent, a protection against dislocation.

Fig. 44.



A C The Cartilages of a joint, varying in thickness according to position.

There is also in several of the joints, as in the knee, a separate, intervening cartilage, so that each joint in which it is found really consists of two joints. By this means the amount of motion over each articular surface is diminished one half.

58. Every joint is inclosed in a *capsule* which binds the bones together, and prevents the adjacent parts from falling in, and being caught between the bones as they move upon each other. This capsule is a continuation of the periosteum, which, instead of closing around the end of the bone, becomes detached from it where the articular surface commences, and, passing over the joint, attaches itself to the next bone. The joint is therefore contained within a sac impervious to air.

Chapter II. ***Section I.***—**56.** Of what does a joint consist?

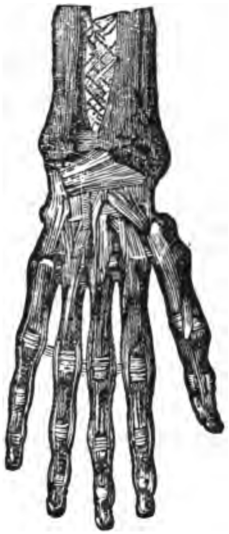
57. Why are not the articular surfaces of bone brought directly together? With what are the articular surfaces covered? How does the thickness vary? How do some of the cartilages tend to strengthen the joints? What is the use of the separate cartilage in certain joints?

58. What is the use of the capsule? How is it formed? How, apart from its strength, as a means of tying the bones together, does it protect the joint?

The close fit of the articular surfaces which form a joint is among the prominent means of protection. The surfaces adhere by atmospheric pressure with a force equal to sixteen pounds to the square inch of surface. It is the same principle which the dentist employs in securing to the roof of the mouth the plate to which artificial teeth are attached. The plate can be loosened, however, by depressing one side so as to admit the air. The joint is more fully protected, because the inclosing capsule entirely excludes the air.

59. In addition to the capsular support of the joints, they are supplied with numerous *ligaments* as protection against dislocation. They are sometimes only a thickened and strengthened state of the capsules at exposed points. Other ligaments are quite separate from the capsule. Fig. 45 represents the inside of the hand with the muscles dissected off, and will give a good general idea of the abundance of ligaments with which the joints are furnished, and the amount of protection which they give.

Fig. 45.



Represents the ligaments which pass from one bone to another in the hand. Also the ligament which connects the bones of the fore arm.

The ligaments are severally adapted to the amount of motion which the joints require. Thus the ligaments of the shoulder joint are, within certain limits, as elastic as India-rubber. Otherwise the joint would be comparatively useless. But the ligaments which bind the square bones of the wrist or foot together

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59. What protection have the joints in addition to the capsules? Are the ligahave scarcely any elasticity. If they had they would answer no good purpose in those places.

Again, there is a striking adaptation in the amount and arrangement of the ligaments to the degree of danger to which a joint is exposed. When a joint is otherwise weak, especially if it is an important one, greater care is taken to protect it by ligaments. In the knee joint, for instance, if the bones were larger the joint would be stronger, but the limb would be more cumbrous. With the size which the bones of the knee have, it might be asked, how its strength may be made the greatest, while yet the freedom of motion is not interfered with. The question is solved in the construction of this joint. Besides a liberal supply of ligaments passing across the joint from bone to bone, outside of the capsule, there are within the capsule two ligaments, originating in the deep groove which separates the external and internal condyles,[17] crossing each other like the letter x (and hence called crucial ligaments), and attached to the head of the tibia (*f g*, Fig. 46). The advantage of this arrangement is that the protection is almost in the centre of the joint, and

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[17] We have here an instance, not uncommon in the anatomy of the body, of several ends attained by the same contrivance. This groove might, at first, appear to be left only to make the bone lighter, and yet give the requisite enlargement of the extremity of the bone, for the purpose of forming the joint. We now see that it answers another purpose, by furnishing the means of attaching, in the most favorable position, those ligaments upon which depends the principal security of the most exposed joint in the system. As this joint is the most exposed one in the system, so the blood vessels and nerves which pass it would be especially exposed to be injured, but for this groove, which furnishes them a passage along the least exposed side of the joints, deep below the surface, and protected from injury by the condyles which rise up on both sides.

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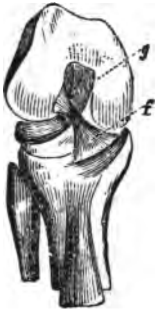
ments separate from the capsules? How are the ligaments adapted by their elasticity to the proper motion of the joints? What other adaptations have they? Explain this adaptation in case of the crucial ligament. Of the round ligament.

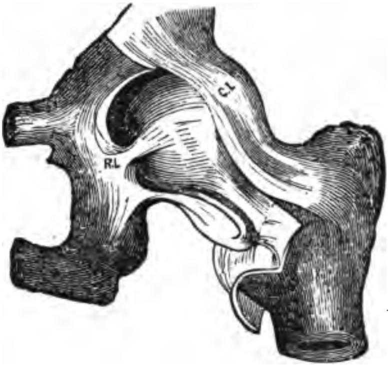
also that the direction of the ligaments is such, that any force tending to cause dislocation, must be exerted in a direction almost lengthwise of one or other of these ligaments. Their position is therefore such as to make them operate to the greatest possible advantage.

Fig. 46.



The back side of the Knee Joint. *f g* The crucial ligaments by which the joint is protected in the centre.

Fig. 47.



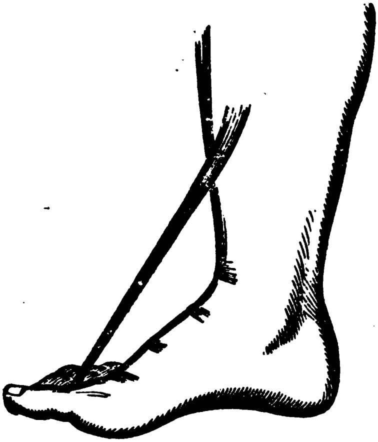
The Hip Joint. R L The round ligament. C L The capsular ligament.

Another instance of a similar kind is the round ligament of the hip joint (R L, Fig. 47), which has very great strength, and passes directly from the centre of the head of the femur to the centre of the acetabulum. It is sufficiently elastic to allow of the requisite motion, but not of motion to such extent as to render dislocation possible without breaking the ligament.

In a few cases there are ligaments passing from bone to bone, to give greater support to the parts where there is no proper joint. Of this kind are the ligaments between the tibia and fibula, and that between the radius and ulna (Fig. 45).

In what instances are ligaments employed to confine bones within proper limits where there are no joints? What other use is made of ligaments?

Fig. 48.



The direction of muscular motion changed by ligaments.

There is another class of ligaments which have an entirely different object. They occur where a tendon is to take a different direction from that of the muscle from which it comes; in the instep of the foot, for example (Fig. 48), where the symmetry of the foot would be entirely destroyed if the tendon which goes to the toes, instead of being tied down into the angle, were allowed to pass directly from the muscle to the points of insertion. Its object therefore is to change the direction of muscular motion.

60. The whole internal surface of the joint, that is, of both cartilages and the capsule, is lined with the **synovial membrane** (represented by the dotted line in Fig. 43). There are also in several parts of the body tubular sheaths for the transmission of tendons, and where the amount of motion is such as to require that the surfaces should be covered with synovial membrane.

This membrane secretes a glairy and very perfectly lubricating fluid, **the synovia**, the office of which is the same as that of lubricating substances used in all kinds of

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60. With what are the surfaces of the joints lined? What is the object of this membrane? What is the office of the synovia? What advantages have the joints over other machinery in this respect?

machinery, to diminish the friction of solids moving upon each other. The joints have, however, these advantages over other machinery, that the synovia is the most perfect lubricating substance known, that it is supplied over the whole surface requiring lubrication, that the quantity is exactly proportioned to the demand, since the amount secreted depends upon the amount of motion of the joint, that it is not supplied at intervals but constantly, and that the old is absorbed as the new is secreted.

Section II.—Particular Joints.

61. The joints are either movable or immovable. We have examples of the immovable joints in the sutures of the head and face, and in the articulations of the teeth with the alveolar processes.

The movable joints are of four kinds.

62. First, those which admit of motion only by the compression of interarticular cartilage. The articulations of the vertebræ, with the exception of the two highest, are of this kind. Each cartilage is firmly fixed to the two vertebræ next above and below it. Instead of two cartilages, as the other joints have, each joint contains but one, but this is of much greater thickness, so that it will admit of compression enough to produce all the motion required. These joints are not supplied with synovial membrane, as there is no motion of surfaces upon each other. The articulation of the bones of the pubis in front is of this kind, though the cartilage is not thick enough to admit

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Section II.—**61.** What are the two kinds of joints? What are examples of the immovable joints? How many kinds of movable joints?

62. What is the first kind? Describe the joints of the spine. Why have they no synovial membrane? What other joints belong to this class?

of much motion. The articulations between the ilium and sacrum, and between the tibia and fibula resemble those of the vertebræ, but each surface of bone has a separate cartilage and is lined with synovial membrane.

63. Secondly, those which admit of motion in only one direction. The articulation of the occiput and atlas allows only the vertical motion, that of the atlas and axis only the horizontal motion, and upon these two joints most of the motions of the head are performed, though the other joints of the neck admit of considerable motion. The elbow, knee, and ankle joints are the most perfect examples of this kind. The articulations of the phalangial bones with each other also belong to this class. They are called hinge joints, and though limited to one kind of motion, the motion is yet very free and extends through a large arc. In the elbow joint, as before stated, the motion is limited both ways by processes of the ulna, but the range of motion of the other hinge joints is determined more by the ligaments than by the form of the bones.

64. Thirdly, the condyloid articulations. The articulation of the lower jaw with the temporal bone belongs to this class. The usual action of this joint is such as to give a vertical motion to the jaw. But the cavity in the temporal bone, which forms the socket, is larger than the condyle of the lower maxillary bone, so that a slight lateral (the grinding) motion is allowed, and also some motion backward and forward. The articulation of the clavicle with the scapula and with the sternum, those of the ribs

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63. What is the second kind? Describe the first and second joints of the spine, and their object. What are the remaining joints of this kind? By what general name are they designated? How is their motion limited?

64. What is the third kind of joints? Describe the articulation of the lower jaw. Name the other joints of this class. What is the peculiarity of the articulation of the radius and ulna? Why is the joint between the wrist and thumb classed with the condyloid joints?

with the vertebræ and the transverse processes, and those of the phalanges with the metacarpal and metatarsal bones are of this kind. The articulations of the carpal bones with each other, and with the metacarpal, also those of the tarsal with each other and with the metatarsal, belong to this class, though the motions in these joints are extremely limited. The articulation of the radius and ulna is composed of two condyloid joints, one at each end, by which the rotary motion of the hand is provided for. The joint between the thumb and the wrist, though of a peculiar construction, is in its motions very much like the condyloid joints.

65. Fourthly, those articulations which admit of free motion in all directions These are denominated ball and socket joints. There are but three joints of this kind In the wrist joint the bones of the carpus are so arranged as to form a spherical surface which is fitted to a shallow socket on the end of the radius. This is a weak joint, not fitted for the support of much weight, but for that freedom of motion by which the hand is adapted to be an organ of prehension. In the shoulder joint the ball of the humerus is received into the glenoid cavity, the edges of which are so raised by cartilage as to form a perfect socket. To form the hip joint, the head of the femur is received into the acetabulum. This is the most perfect ball and socket in the system, both by the shape of the bones which go to form it, and by the appendages of cartilage which raise the rim of the socket.

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65. What is the fourth kind of joints? What ar they called? What joints are included in this division? Describe each joint.

CHAPTER III.—OF THE MUSCLES.

Section I.—General description of the Muscles.

66. THE muscles are either *voluntary, involuntary,* or *mixed.* The heart and stomach are instances of involuntary muscles, that is, muscles which contract and relax under a stimulus which is independent of the will. Those muscles upon which respiration depends are both voluntary and involuntary, that is, they contract and relax with regularity when the attention is withdrawn from them, but they can still be controlled by the will.[18] Those muscles upon which the motions of walking, eating, winking, writing, etc., depend, and which, in a state of health, contract and relax only in obedience to the will, are called voluntary muscles.

67. Those muscles which are partially or wholly con-

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[18] It is not improbable that these mixed muscles (being supplied with voluntary and involuntary nerves) may be constantly stimulated by the involuntary nerves, and uniformly obey them when there is no opposing influence, but that the power of the voluntary nerves is superior when the will is active, and controls their motions temporarily. Unless these muscles were involuntary, life could be continued only so long as we could retain the waking state, and direct our attention to the process of respiration. It is also very important that these muscles should be voluntary, so that we may control the degree of force with which respiration is effected, and also control the length of each act of respiration; otherwise, we could have no control over the voice. We might be able to articulate while the air was passing out of the lungs, but we would be unable to vary the compass of the voice at all, and if the act of expiration should terminate while we were pronouncing a word, we should be unable to complete it till the next expiration.

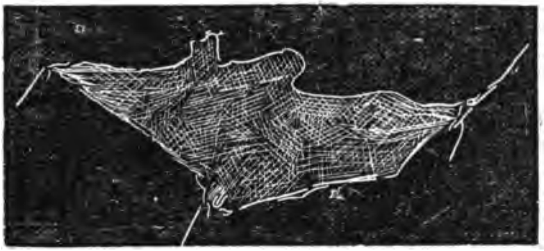
Chapter III. ***Section I.***—**66.** Into what classes are the muscles divided? Give examples of each class.

67. What do the voluntary and mixed muscles constitute? How are they situated? What effect have they upon the general form of the body?

trolled by the will constitute the lean meat of animals. They lie upon the bones, filling the depressions, and giving the general fullness and roundness of contour which belong to the different parts of the body.

68. That end of the muscle which is not movable is called the **origin.** The point where the power is to be exerted is the **insertion.** This distinction, however, does not always hold, because in a few muscles each extremity is capable of becoming alternately the fixed and movable point. The fleshy part (the *belly* of the muscle) consists of ultimate fibres, too minute to be well exhibited except by a glass of high magnifying power. Several of these fibres are collected together into a bundle (or fasciculus),[19] and inclosed in a sheath of cellular substance.[20] A muscle

Fig. 49.



A film of Cellular Membrane.

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[19] In a piece of beef which has been cooked till it is very tender, the fasciculi of a muscle, inclosed in a very attenuated membrane, are well exhibited and easily separated.

[20] The cellular tissue consists of membrane of extreme tenuity (Fig. 49), and pervades all parts of the system. The membrane stripped from the leaf of fat taken from a fattened animal, consists of several thicknesses of cellular tissue. The loose, bladder-like membrane, by which the skin of animals adheres to the muscular parts below, is cellular membrane. It

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68. What part of the muscle is called the origin? What the insertion? Why cannot the distinction always be made? Describe the fleshy part of the muscle.

consists of a collection of these fasciculi inclosed in another firmer sheath of cellular substance.

69. At the extremities of the muscle the cellular sheaths which inclose the several fasciculi, and that which incloses the whole muscle, becoming free from muscular fibres, are condensed into a firm, inelastic *tendon*. When the muscles can conveniently be situated near the place where the power is to be exerted, the tendons are very short, and in many cases there is no distinct tendon formed. Otherwise tendons, often of considerable length, are employed.[21]

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forms a loose network which pervades very generally the other tissues of the body. It exists in the bones. It is this membrane into the cells of which adipose matter is deposited to form the fat meat of animals. It is this membrane which incloses, with a sheath so thin as to be scarcely visible, the fasciculi of ultimate muscular fibre. It is the same membrane which, in a condensed state, forms at one time the tough leathery sheaths (fasciæ) by which the whole of a muscle, or several muscles, are inclosed, and, at another time, the tendons of the muscles or the ligaments of the joints.

[21] A correct idea of the use and action of tendons may be obtained by examining the leg of a fowl. The tendons are the small white cords which are prolongations of the muscles situated in the thigh ("drum-stick"). By pulling the cords on one side the parts of the claw contract; by pulling those on the other side, the claw opens.

We often find a highly artificial arrangement of tendons, and one which as fully proves an intelligent contriver as any complicated arrangement in a work of human skill. Thus the muscles are often at a distance from the place where the power is to be exerted, and the power is transmitted by tendons of the exact length necessary to effect the motions required. When a muscle is in the way of a tendon of another muscle, a slit is found in the first muscle through which the tendon of the other passes. A slit of this kind is made in the stylohyoid muscle for the tendon of the digastric muscle to pass. This last muscle has also another peculiarity, that the belly of it is divided into two parts which are connected by a tendon, and in order to change its direction, this tendon passes through a loop of cellular substance attached to the hyoid bone. The tendon (*a*, Fig. 50) which

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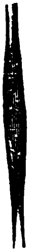
69. How are tendons formed? In what cases are the muscles without tendons? Then what is the use of tendons?

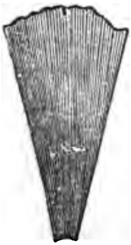
70. The muscles, though all composed of bundles of fasciculi, are yet very different in *form.* In some the fasciculi are all parallel with the general direction of the muscle, as in Fig. 51, and it becomes spindle-shaped. Sometimes they diverge from a point and the muscle is fan-shaped, Fig. 52. Sometimes the fasciculi are oblique to the general direction of the muscle, and are arranged along one

Fig. 51.



A spindle-shaped Muscle.

Fig. 52.

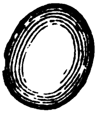


A radiated Muscle.

Fig. 53.

A penniform Muscle.

Fig. 54.



A sphincter Muscle.

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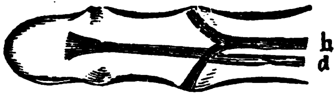
bends the last joint of the finger, lies under the tendon which goes to the second joint; and in order to let this lower tendon pass the second joint, the upper tendon (*b*) is divided and attached at two points, and the lower tendon passes between the two branches. The muscular power exerted on the top of the foot first has its direction changed by passing under the transverse ligaments of the ankle. The muscular power exerted on the bottom of the foot first has its direction changed by the tendons passing around a groove in the heel similar to the groove in the wheel of a pulley. The trochlearis muscle gives a motion to the eyeball directly opposite to that which would be produced if it were inserted by a straight tendon into the top of the ball. This reverse motion is produced by the tendon passing through a ring in the angle of the bone above the inner corner of the eye, and then going back to be inserted into the top of the ball.

Fig. 50.



a The ligament which passes under the bifurcated ligament *b*, to go to the last joint of the finger.

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70. Describe the several forms which the muscles are found to take.

or both sides of a tendon, as in Fig. 53, and the muscle is said to be penniform. Still others are circular, and by contraction close the opening which they encircle, as the mouth, the eye. They are called orbicular or sphincter muscles, Fig. 54.

71. The general principle in the *arrangement* of the muscles is, that they are as near as possible to the places where the motions are required. This is the case in the neck, head, and trunk. There is, however, a wide exception to this law in the position of the muscles which move the extremities. Here, the rule is, that the muscles are placed as near the trunk as possible. The object is to give to the limbs lightness and adaptation to free and rapid motion. Hence the muscles which move the shoulder are on the body, those which move the elbow are on the arm, and those which move the wrist and fingers are on the fore-arm. The same general arrangement exists in reference to the lower extremities. So far as mechanical power is concerned, the situation of the muscle might be, at least in part, reversed. Those, for instance, which move the elbow joint might have been in the fore-arm, etc., but it is obvious that the hand would have been heavier and more unwieldy. Certain very weak but quick motions are, however, performed by muscles which are situated in the hand and along the fingers. But these muscles are so small as not to add perceptibly to the weight of the hand.

72. The three principal circumstances noticeable in reference to muscular action are, First, **rapidity of the**

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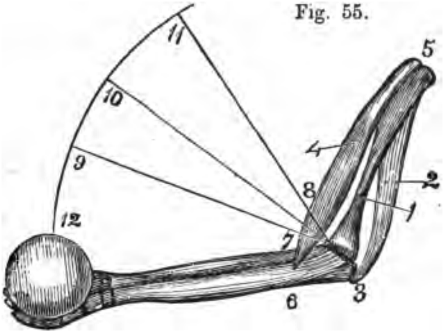
71. What is the general law for the position of the muscles? In what parts of the system does this arrangement prevail? In what parts of the system does a different principle prevail, and what is it? What is the object of it? Are there any muscles situated on the hand and on the fingers? What is the size of the muscles, and what kind of motions do they perform?

72. What muscles act without mechanical disadvantage? Is this generally the case? Are the muscles best fitted to exert great force or to produce a wide range of motion? How is force converted into motion?

motions produced. Some of the muscles, as the heart and the straight muscles of the abdomen may exert a power equal to the force with which they contract. But such is not the case generally, and particularly with those which move the limbs. The force with which they contract seems to be abundantly supplied in the system, but the constitution of the muscle is such, that an amount of contraction equal to the range of motion required is impossible. There is, therefore, such a construction of the framework, and such a disposition of the muscles, that a large supply of muscular power, with a limited amount of muscular contraction, shall be converted into a wide range of motion. The muscles are said to act at a disadvantage, which is true so far as power is concerned, but it is simply an exchange, a contrivance to relinquish power which the system can spare, in order to secure greater and quicker motion which it needs.[22] Thus, in Fig. 55, by a small amount of muscular contraction, the hand is

Fig. 55.



1 The humerus. 2 The muscle by which the joint is straightened. 3 Its insertion. 4 The muscle by which the elbow is bent. 5 Its origin. 6 Its insertion. When the muscle 4 contracts by an amount represented by 7. 8. the amount of motion of the ball will be represented by 9. 11. There is a loss of power which is compensated by an increase of motion.

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[22] The muscles which bend the elbow must exert a force equal to about twenty-five times that of the weight raised by the hand. It seems incredible that a force of more than half a ton should be exerted by the two small muscles which bend the arm ; yet such is the fact. Still, that power would be of little service to us if we could not change it, in part, into

made to take successively the positions of 9, 10, and 11. If a muscle could have been attached at 12, and made to act in the direction of the arc, there would be no loss of power, but no muscle could perform the amount of contraction which would be necessary.[23]

73. Secondly, **muscular antagonism.** Every voluntary motion of the body depends not only on the contraction of one muscle or set of muscles, but also on the relaxation of another muscle or set of muscles. Thus a perfect *antagonism* of muscular power exists throughout the system. When the motions performed are principally those of bending and straightening the joints, the two classes of muscles are called flexors and extensors.

74. Thirdly, many of the motions are the *combined result* of the contractions of several muscles. Each muscle has generally a distinct motion to perform, but there are cases in which the fasciculi of a muscle may contract independently of each other, so that one muscle may per-

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velocity; that is, if we could not move a hand or a foot to a greater distance at once than the extent of the muscular contraction of even the longest muscle.

[23] But instead of seeking occasion to lengthen the muscles, and thus increase their range of motion, there seems to be an opposite tendency. Thus, the penniform muscle is an arrangement to increase the number of muscular fibres of which a muscle consists, and therefore to increase the power with which it contracts, but at the same time to shorten the fibres, and therefore diminish the amount of contraction. This arrangement is most conspicuous in the muscles which straighten the knee, where a great amount of contraction would be useless, but where great power is necessary to control a joint bearing the whole weight of the body, and where the muscles must act so disadvantageously.

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73. What besides the muscular contraction is necessary to produce motion? What relation of the muscular power is established in the system? What are those muscles which bend the joints called? Those which extend the joints?

74. How can the same muscle produce more than one kind of motion? Do the motions often depend each upon several muscles? Give instances.

form several different motions. More frequently, however, a single motion is the result of contraction of several muscles. Thus the tones of voice depend upon the position and tension of cords which are controlled by several muscles. To produce these almost infinitely varied tones at pleasure, implies an instantaneous and perfect control of these muscles. So the rapid and perfectly accurate motions of which artisans, musicians, and especially jugglers are capable, depend upon controlling accurately a large number of muscles.

75. This perfect control may be more easily acquired by some persons than others, but it is never gotten without effort. It is the result of *training*. We see this in the gradually increasing correctness of pronunciation which the child acquires, in the efforts which the student is obliged to make in getting the sounds of a foreign language, in learning to write, to knit, to play on a musical instrument, or in acquiring any other kind of motion which requires skill.

We may lose, by disuse, the control which we have once had of muscles. Thus, if a bone be broken and we are obliged to relinquish the use of a limb wholly, even a few weeks are sufficient to place it quite beyond our control. There are muscles properly situated for moving the ears, but they have been so long out of use, that it is hardly probable that the use of them could again be recovered.

76. The muscles produce their effects by contraction, diminution of length, and the power which they are capable of putting forth at once, if it could be made to centre

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75. How may this control be acquired? Give instances. Give an instance in which this control is temporarily lost. Give an instance in which it seems to be lost beyond the power of recovery.

76. How do the muscles produce the motions of the body? What is the nature of the power which produces those changes?

at one point would be equal to several tons' weight; but of the nature of the muscular power we know nothing. That is, we do not know why a muscular fibre should become longer or shorter when we will it to be so. We only know that it does thus obey the will. It is one of the modes of the manifestation of the vital force, which will be considered in the chapter on respiration. All that we can do is to inquire into the conditions which seem to be essentially connected with this *manifestation of force.*

77 In the first place, every exertion of muscular power is connected with **a change in the substance of the muscle**, some portion of it being decomposed and returning to a lifeless state. It is by this lifeless matter (metamorphosed tissue), taken up by the blood in its circulation through the muscles, that the bright arterial red which it had when it left the heart, is changed to the dark color which it has when it comes back to the heart.

The portion thus decomposed was held in a living state by a certain force. This force is set free when the portion becomes lifeless, and can then be made use of for mechanical results; that is, to produce muscular contraction. This return of living tissue to a lifeless state is not, therefore, accidental, but is necessary to muscular contraction, and is in exact proportion to the force of contraction required.

Hence it is that those employments are the most exhausting which may not be very laborious but which incessantly exercise only one class of muscles. They require too great an amount of decomposition of this one class of muscles. The accountant who has done nothing for ten hours but sit and move the small muscles of the hand in writing, is

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77. How are the muscles affected by muscular contraction? Why is this decomposition necessary? What effect does this have upon the blood? What employments are most exhausting, and why? How is injury from such employments to be guarded against?

more weary than the person who has labored hard in the field and brought all the muscles of the system by turns into vigorous exercise.[24] Constant writing, sewing, turning a wheel, playing on a piano, or any employment which requires the use of one set of muscles exclusively, is wearisome and injurious, unless relieved by a large amount of rest and recreation.

78. In the second place, the healthy action of the muscle requires an **active circulation of the blood**, for this constant destruction of muscular tissue must be connected with as constant renewal, and the blood is the means both of removing the decomposed muscle and supplying the material for the new.

The energy with which the blood circulates is dependent in a great measure upon exercise of the whole system. Exercise may operate in several ways to stimulate the circulation, but part of its effect is merely mechanical. Relaxation of the muscle allows the blood to flow into it, and contraction forces it out, and as there are contrivances in the blood-vessels to prevent its rushing backward, both contraction and relaxation of the muscles tend to establish a more energetic circulation, and therefore a more complete repair of the waste occasioned by decomposition.

79. The circulation of the blood in the muscles adapts itself in quantity to the amount of exertion which these

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[24] It is noticed by teamsters that their horses weary much quicker when the road is uniformly level, and the effort required is not great, than on uneven roads, where the draught is often much greater. In the latter case different sets of muscles are exercised alternately.

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78. What is the second condition of muscular power? Why is this active circulation necessary? Upon what does such a circulation depend? How does exercise mechanically promote the circulation of the blood?

79. Upon what does the amount of circulation in the muscles depend? Why does a person of active habits need more circulation in the muscles than a sedentary person? Why should a change from one mode of life to another be gradual?

muscles ordinarily make. Hence the muscles of a person who is accustomed to active employment receive a large amount of blood, and when he is prevented from putting forth his accustomed activity he becomes restive. For such a state of rest his amount of circulation is a diseased one. If, on the other hand, a person of sedentary habits attempts to perform in a day what would be a day's labor for a working man, he effects an amount of decomposition of muscular tissue altogether disproportionate to the amount of renewal which the ordinary supply of blood can furnish in the same time, and the result is extreme exhaustion. The change from one mode of life to another can be safely made only by so slow degrees, that the power of adaptation in the system shall adjust the circulation in the muscles to the demands made upon them.

80. This adaptation in the supply of blood to the amount of effort put forth, is however subject to two modifications. During the period of childhood and youth, the new muscular fibre is furnished in large quantity, but it is for the purpose of growth, and not because muscular effort and muscular decomposition had been great. In fact such persons often put forth and are able to put forth but little muscular power. It is also found that any class of muscles which is subjected to a great amount of exercise continuously, receive more muscular fibre than is decomposed, and they become increased in size; that is, the muscular fasciculi become more numerous. Instead, therefore, of requiring a muscle to perform extra labor continuously by a more rapid decomposition and renewal of the muscular fibre (which, beyond a certain degree, would generate disease), the large supply of blood which exercise induces

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80. What is the first modification to which this relation of circulation and muscular effort is subject? What becomes of the nutriment furnished by the circulation of young persons? What is the second modification?

goes to furnish a large number of fibres to perform the labor.[25]

81. Muscular action is dependent on **nervous influence.** The nerves do not produce muscular power, for we may often be unable to exert this power while the nerves are uninjured. But they control (or the brain, through the nerves) the vital force which is employed in muscular contraction. Hence when the connection between a muscle and its nerve is interrupted there can be no muscular action. Hence also it is, that under excitement or a vigorous effort of the will the muscular power may for a short time be so wonderfully increased. In a very short time, however, such energetic action of the muscles will produce exhaustion; and even moderate muscular action will at length bring on weariness. This weariness may arise from a failure of the vital force, or too great decomposition of the muscular tissue. In either case it is an indication from our constitution that the system requires rest.[26]

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[25] Sculptors and painters study carefully the external changes which the muscles undergo from change in the mental states, from exercise, use, excitement, disease, etc. The best representations of Hercules (the embodiment, among the ancients, of their ideas of physical power) exhibit the muscles as very large, and those in the back and arms as specially large, firm, and well defined.

[26] It would be the natural order to follow this section by a description of the muscles individually. But these descriptions involve the use of technical terms in great numbers, and a minute knowledge of osteology. These descriptions have therefore been introduced in an appendix, and can be referred to by those who have leisure and taste for more difficult study.

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81. What is the third condition of muscular power? Why are not the nerves the source of power? What is the office of the nerves in reference to the muscles? How does a high degree of excitement affect the strength of a person? What is the condition of the system indicated by weariness? What is the instruction which it conveys?

GENERAL QUESTIONS ON THE PRECEDING CHAPTERS.[27]

Define Anatomy and Physiology. How many systems of organs are to be examined? Show in their order why these systems are necessary.

CHAPTER I.—Of what does this chapter treat? What are the subjects of the sections in this chapter?

SECTION 1.—What are the objects of the osseous system? Give the process by which the osseous skeleton is formed. What is the composition of ordinary bone? What division of the bones according to their form? Explain the structure of the bones. How do bones increase in length and diameter? Describe the periosteum.

SECTION 2.—What are the two divisions of the bones of the head? What is the structure of the bones of the cranium? Name the bones of the cranium, and give their position. What are the processes of the bones of the cranium, and where are they situated? What is the form of the cranium? What is a suture, and what ones are found in the cranium? What are the purposes of the cranium? How is it fitted to accomplish each of these purposes? Name the bones of the face and give their position.

SECTION 3.—What division is made of the bones of the trunk? Of what does the spine consist? Describe a vertebra and its processes. Explain the differences in the vertebræ in different parts of the spine. How are the bones of the vertebral column connected together? Describe the intervertebral foramina and spinal canal. What are the objects of the spine? How is it fitted to effect each of these objects? Describe the sternum. The ribs. The use of the thorax. The pelvis. Its use.

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[27] A list of general questions has been appended to this part, at the close of Part 2 and Part 3, for the purposes of reviews and examination. The questions are designed to test the knowledge of the pupil, and others of a similar character will be easily added by the teacher. It is recommended that, as each section is completed, there be a review of it by some such general questions as have been given above. At the end of a chapter let it be reviewed by sections. Let Part 1 be reviewed by chapters, that is, let the object of each chapter be given; then each chapter by sections; then each section by topics; and thus the view of the subject which the learner acquires will be a connected one.

This kind of general review should not, however, be allowed to take the place of more rigid reviews. Thoroughness can be acquired only by special attention in this respect. Pupils are often averse to reviews, because they are anxious to hasten the completion of any subject of study, and because, in reviewing, the novelty of the subject is gone. The most profitable part of their study, however, is the reviewing. The text has been constructed with great brevity, in order to give sufficient opportunity to be thorough; but if time will not admit of completing the study, let it be thoroughly reviewed as far as it is studied.

Section 4.—What are the bones of the upper extremities? For what uses are the bones of the upper extremities intended? In what consists their adaptation to these uses?

Section 5.—What are the bones of the lower extremities? What are the purposes designed to be accomplished by them? What are the adaptations to each of these purposes?

Chapter II.—What is the subject of this chapter? Section 1.—How is a joint formed? What are the four appendages of joints? What are the four peculiarities of ligaments adapting them to the amount of motion and kind of danger? For what other purposes are ligaments used? In what respect is the synovia adapted to its uses? Section 2.—What division is made of the joints? How many kinds of movable joints? Give instances of each kind.

Chapter III.—What is the subject of this chapter? Section 1.—What division is made of the muscles? What are the muscles here considered? What are the forms of the muscles? What is the general arrangement of the muscles? What three principles prevail in reference to muscular motion? How does practice affect our control of the muscular power? What is the muscular power? What three laws relating to the exercise of this power? What consequences follow from the first law? What affects the amount of circulation of blood in the muscles? Under what circumstances is the amount of circulation more than proportioned to the muscular power possessed? What is the third law? What is the physical cause of weariness, and what is its import?

PART II.

THE NERVOUS SYSTEM.

THE NERVOUS SYSTEM INCLUDES THE BRAIN, SPINAL CORD, NERVES, AND THE EXTERNAL SENSES.

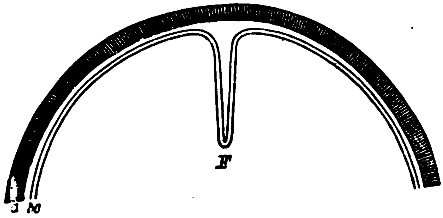
CHAPTER I.—OF THE BRAIN, SPINAL CORD, AND NERVES.

Section I.—The Brain.

I. *The Enveloping Membranes of the Brain.*

82. There is a firm membrane called **the dura mater,** which is closely attached to the interior surface of the cranium, and may be regarded as an internal periosteum. In several instances the membrane is not attached continuously to the bone, but leaves loose duplications (*F*, Fig. 56), by which the brain is partitioned off into separate portions. One of these folds is the *tentorium.* It is a nearly horizontal membrane, arising from the ridge at the top of the posterior fossa, thus

Fig. 56.

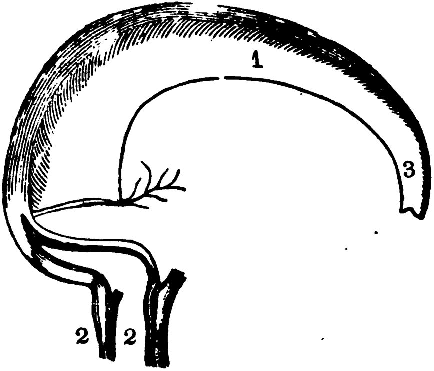


A vertical, transverse section of the Cranium. *a* The skull. *b* The dura mater. *c* The arachnoid membrane. *F* The falx cerebri.

Part II.—What is included in this system? ***Section I.***—**82.** What are the three membranes which inclose the brain? Describe the dura mater. Describe the three partitions of the brain produced by the dura mater.

separating the cerebrum from the cerebellum. Another partition, which is called **the falx cerebri** (1, Fig. 57), arises from the ethmoid bone, follows along the sagittal suture, and becoming wider as it extends backward, terminates at the tentorium. Another much smaller fold of the dura mater, called the *falx cerebelli*, extends from the tentorium to the magnum foramen.

Fig. 57.



1 The falx cerebri. 2, 2 Two large veins by which the blood is returned from the head. 3 The forehead.

83. The arachnoid membrane is an exceedingly thin film, and is attached to the interior surface of the dura mater. It secretes a fluid in small quantity, but sufficient to keep the surface moist, and diminish the friction occasioned by the slight motion of the brain within the cranium.[28]

84. The pia mater is a thin but firm membrane not attached to the arachnoid or the dura mater. It lies next to the brain, dipping into its substance at the fissures, and forming the only proper envelope of the brain.

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[28] There is a constant secretion of this fluid and as constant an absorption of it. This membrane, in certain conditions of the system, and particularly in childhood, is apt to take on inflammation, when the secretion becomes too abundant, and results in dropsy of the head (hydrocephalus).

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83. Describe the arachnoid membrane. What is its office?

84. Describe the pia mater.

II. *General Structure of the Brain.*

85. The brain occupies nearly the whole cavity of the cranium. It is divided into right and left hemispheres, the falx cerebri lying between them. The base of the brain is divided on each side into three *lobes,* corresponding with the three depressions in the base of the cranium. That portion which lies in the posterior fossa and under the tentorium, is the *cerebellum;* the remaining, and by far the largest portion, is the *cerebrum.*

86. The medulla oblongata (Fig. 58), though not a part of the brain but of the spinal cord, of which it is simply a prolongation above the magnum foramen, is situated within the cranium. It continues of nearly the same size as the spinal cord for about an inch, and then becomes enlarged into a bulb (*a*) called the *pons varolii.*

Fig. 58.

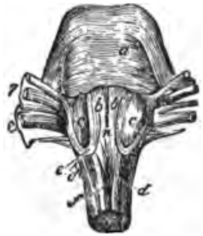
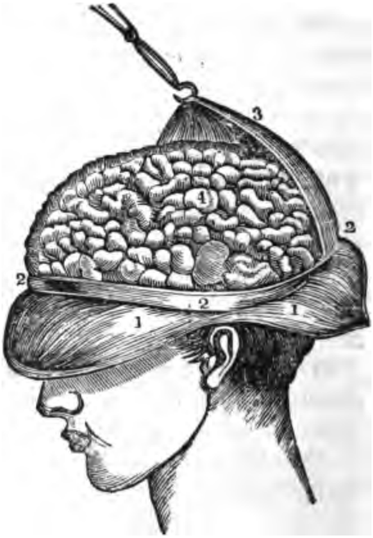


Fig. 59.



1, 1 The integuments of the head turned down. 2. 2 The edge of the remaining part of the cranium, the upper part having been removed. 3 The dura mater. 4 The convolutions and anfractuosities of the brain.

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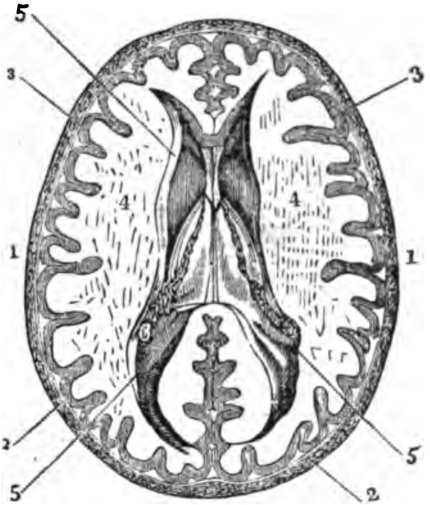
85. Where is the brain situated? State the divisions of the brain.

86. What besides the brain does the cranium contain? Describe it.

87. The external surface of the cerebrum presents numerous irregular elevations, called *convolutions* (4, Fig. 59), which are separated by depressions (*anfractuosities*). These depressions are better seen in the horizontal section, Fig. 60, and are produced by folds of the pia mater dipping down for half an inch or rather more into the substance of the brain.

88. The two hemispheres of the cerebrum are connected by a white fibrous substance, **the corpus callosum** (*e*, Fig. 65), situated below the falx cerebri. Its fibres run transversely, as seen at *d e d*, Fig. 61. Between the corpus callosum and the base of the brain are five cavities called *ventricles*, the larger two of which are seen at 5, 5, Fig. 60.

Fig. 60.



A horizontal section of the Cranium and Cerebrum. 1, 1 The cranium. 2, 2 The dura mater. 3, 3 The cellular substance of the cerebrum. 4, 4 The tubular substance. 5, 5 The lateral ventricles of the brain.

89. The brain is composed of **cellular and tubular substances.** The first is a gray, ash-colored, pulpy mass, the other is dense, white, and fibrous. In the cerebrum

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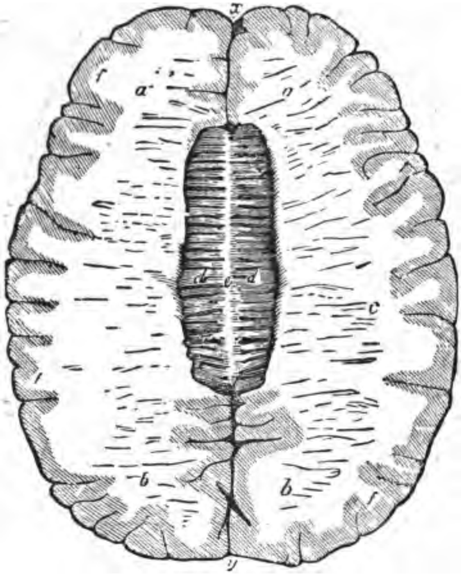
87. Describe the external surface of the brain.

88. How are the hemispheres of the brain connected? Describe the corpus collosum and the ventricles.

89. Of what is the brain composed? Describe these two substances. How are they situated in the cerebrum? In the medulla oblongata? In the cerebellum?

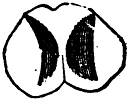
the cellular or gray substance is exterior (3, 3, Fig. 60), lying immediately under the pia mater, and following it wherever depressions of that membrane occur. The tubular or white substance (4, 4) constitutes the central portion of the cerebrum. In the medulla oblongata the gray portion is central, and the white exterior (Fig. 62). In the cerebellum the two substances are arranged in concentric layers, giving, when a vertical section is made, the branching appearance (seen above, *b c* in Fig. 65) called the *arbor vitæ.*

Fig. 61.



A horizontal section of the Brain at a higher level than the preceding section. *a b c* The white substance. *f* The gray portion. *d e d* The corpus callosum.

Fig. 62.



A cross section of the spinal cord. The dark portions represent the ciner itious portion. The cineritious portion is found in the central part of the medulla oblongata also.

III. *Functions of the Brain.*

90. The brain is a pulpy mass, distinguishable into parts

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90. What reason have we for supposing that the brain is a highly organized substance? Can we, from a study of its organization, determine its functions? In what way are we to determine its functions? What are they?

by differences in color and structure; but it has not, like the skeleton, the muscles, or the eye, such a relation of parts that we can see their adaptation to the offices which they perform. The care, however, with which the brain is protected, the amount of blood with which it is supplied, and the connection existing between the health or disease of the brain and the proper or disordered action of other parts of the system, lead us to believe that it has a highly complex and perfect organization. But the most accurate examination of its intimate structure has thrown no light upon the mode of its operations. We cannot, therefore, as we can in most other parts of the system, study its organization, and from this infer its functions. These we are left to determine simply from the phenomena which it exhibits.[29] These phenomena justify us in regarding it as a *repository of power* and as the *organ of the mind.*

91. The brain does not, so far as we know, originate any of the forces of the system, such as those upon which

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[29] This we ought to expect from the *peculiarity* of its functions. Considering it as the organ of the mind, what possible adaptation can we conceive? It is conceivable that beings, in other respects like us, should have been created without hands (or any other important organs would serve for illustration), and they would be able to form some idea of the kind of organization which would be necessary to fit us for prehension, just as we can study out the best construction of a loom, or a steam-engine. But a statement of the question as to the organization adapted to the operations of the mind, makes the thing at once ludicrous. What organization, for instance, would be a suitable one to enable the mind to have the feeling of pain, or the perception of form or color.

The relations of mind to matter—the way by which they affect each other—are so completely beyond the comprehension of man, with his present capacities, that it is only surprising that the idea should ever have been entertained of *discovering* in the organization of the brain any adaptation to its functions.

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91. Is the brain the source of power? What agency has it in reference to the forces of the system digestion, the circulation, and other phenomena of life depend. But, however these involuntary forces are originated, it is a *repository* of them; it appropriates and controls them. Hence when the brain is diseased, these phenomena of life are more or less disturbed. The brain does not, however, exert this control by means of the mind. These actions are removed from the control of the mind, and such removal is essential to life; for the mind requires rest and sleep, and all the operations which depend upon it must, during this suspension of mental activity, be suspended.

92. But the most important function of the brain consists in its being an **organ of the mind.**[30] This, in fact, embraces three functions, for the mind may be acted upon by external objects, it may act upon them, or it may be active with its own ideas, without reference to its relation to external objects. That is, the brain is the organ of the mind in sensation, in volition, and in reasoning.

93. The brain is the organ of the mind in *sensation.* The mind is acted upon by external matter through the agency of the senses. We can trace the operation of physical agents, such as light, odors, etc., till they have reached,

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[30] The preponderance of facts compels us to come to this conclusion, though there are remarkable cases of injury to the brain without permanent, and often without temporary, derangement of the mental operations. Thus, the skull may be broken, or parts of it shot away, and a large amount of brain removed without producing idiotcy or insanity. In Vermont, a few years since, a rod of iron of an inch in diameter, and two feet long, was driven, by the unexpected discharge of gunpowder, through a man's head, entering the face and coming out near the top of the head on the opposite side, and yet the man recovered both his health and his reason.

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92. What is the most important function of the brain? What three objects does it accomplish as such?

93. How far can we trace the operation of physical causes in producing sensations? Can we see in what way the brain operates in producing sensations?

through the appropriate organs, the nerves of sensation, when the mind comes at once to the sensation and perception of the external object. If the nerves which connect these organs of sense with the brain be impaired, this state of mind does not follow. We may, therefore, regard the brain as the organ of the mind in becoming aware of the existence and acquainted with the properties of external objects.[31]

94. The mind cannot affect external matter directly. Whatever effects it produces are the result of contraction and relaxation of the muscles. The power is not, however, in the muscles themselves; for if the nerves which connect them with the brain be severed, the muscles are no longer capable of contraction and relaxation. It is equally true that the power does not consist in the mind, the will; for after we have put forth power for a limited time we become exhausted, and when this exertion has been continued long enough, the most vigorous efforts of the will fail to cause contraction and relaxation of the muscles; the power which the mind had before controlled

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[31] This inference rests upon the fact that whenever we can trace these physical causes up to the brain, this also being in a healthy state, the next thing of which we are aware is a certain state of mind. The brain lies between the organ of sense (as the eye, for example) and the mind. Hence we must regard the brain as essential to the result—as having something to do—as part of the machinery. In what way it is essential is a matter in which we are, and must remain, profoundly ignorant.

It is proper here to remark that this is not a case standing by itself in any important respect. We know as little why fuel will burn, or any other phenomena take place. We can establish the conditions of combustion and see the event follow. Why such event follows such conditions we know not; and we are compelled to regard the result as always the direct work of uncreated power.

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94. How does the mind affect external objects? Is the power in the muscles? Is it in the mind? How is this proved? What agency has the brain in reference to this power?

is spent. When sufficient time and other means have been furnished for replenishing the available vital force, the mind again possesses power over the muscles. The brain is then *the means by which the mind manifests its volitions* in producing muscular motion.

95. By means of the senses we obtain the ideas of color, form, weight, taste, sound, etc. These original ideas suggest necessarily others, such as that of our own existence, of a material world, of a First Cause, etc. All these ideas are variously connected with emotions, such as pain, delight, gratitude, aversion, etc. These ideas are the furniture which the mind receives directly and indirectly from the external world. All these ideas we can recall, compare, and reason upon. These operations of reasoning proceed, to a certain extent, in a uniform manner. There is a great diversity, but still there is what we call a rational state of mind, in opposition to one which we should call insanity. The mind reasons in a uniform manner, obeys certain laws in its mental processes, unless the brain has suffered injury. In a diseased or mutilated condition these operations become irregular, and the person is insane. Insanity is a diseased condition of the brain. In the *reasoning processes* of the mind we may, therefore, consider the brain as the physical agent.

96. Such are the general functions of the brain, or perhaps we should say, the brain and spinal cord. It is not necessary in this place to inquire as to the special functions of particular parts of the cerebral system, since we may, without such inquiry, learn its general functions, and the practical rules to be observed in reference to it.

97. The first principle of practical importance is that

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95. How do we obtain the ideas of color, form, etc.? What other ideas do these suggest? What use do we make of these ideas? In these reasoning processes, how is it shown that the brain is the physical agent?

97. What is the first condition in order that the brain properly perform its

the brain, in order to perform its functions properly, **must be exercised.** The same principle which governs the other parts of the physical system should govern the brain. It is as natural for the child to think as it is for him to play, and the fact that both promote his happiness is proof that both are proper and necessary for him. Indolence of the brain, like indolence of the muscular system, may, however, from circumstances, become a habit. It is the restlessness, the absence of enjoyment thus relinquished which, in a large proportion of cases, drives the individual to seek the stimulus of intoxicating drinks. But the teaching of nature is to employ the brain in thought, and thus escape the necessity of such stimulants.

98. This natural tendency to think will, when properly guided, as certainly develop the mental faculties as proper use of the limbs will develop bodily strength. To do this is the main object of general education. In order to guide this tendency aright, it should in the first place be allowed scope; it should not be repressed. And hence the inquisitiveness of children, even if it be sometimes troublesome, should be allowed a wide range, and should often be stimulated. The gratification of this curiosity and inquisitiveness is the reward of effort by which our Creator would stimulate us to new effort.[32] In the second place, the

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[32] This reward always follows effort. The complaint often made by scholars that their studies are uninteresting, generally rests upon the fact that the studies have not been attended to with sufficient care. The truths have not been comprehended. Everything of the nature of mental acquisition must, from our constitution, give us pleasure. Not that it will give every person the same degree of pleasure, for there are obviously different susceptibilities to pleasure—and there are diversities of taste, so that equally susceptible persons will enjoy different kinds of mental occupation

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functions? What is the natural inducement to exercise the brain (that is, to think)? To what physical evils does neglect of it lead?

98. For what was this tendency to exercise the brain given us? What are the three rules by which it should be guided?

brain should be allowed the necessary relaxation, so as not to become exhausted, and thus awaken a dislike for renewed effort. In the third place, its exercise should be varied within certain limits, so as to give diversity of occupation, and yet not so much or so frequently as to discourage continuous and earnest application.

99. But besides a general activity of the brain, it is possible to give it special skill. It is like the enlargement of the muscles to fit a man for any particular employment. Perhaps the exercise of the brain will not increase its size, but it is certain that it will increase its power in any given pursuit. We see this increase of power in the salesman, the accountant, the politician, the enthusiast in any employment. This is a prominent object of professional education.[33] The brain is as subject as any other physical organ to that wonderful law of habit; it acquires skill, power, and ready obedience to the will by effort continually repeated.[34]

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very differently. The general principle, however, is still sustained, that knowledge always pleases, and it is the observation of all teachers, that those who apply their minds with the most assiduity, are the ones who most enjoy their studies.

[33] In many respects a general and professional education are the same thing. It is not possible to train and discipline the mental powers generally, without doing something toward preparing the individual for professional success. Nor is it possible to confine the attention to strictly professional study without increasing generally the mental powers. It is true also that facts must be learned in both general and professional study. Still, there is the broad and important distinction between general and professional education that the one proposes the general discipline of man as a thinking being, and the other proposes a special discipline, as a preparation of him for a limited and prescribed course of life. To confine education to the first, would be like securing a large muscular development, while the individual is ignorant of any of the processes of useful

99. What advantage does the brain receive from special training? Will it increase the volume of the brain? Give instances in which special power is acquired. In what does this special training consist?

100. The brain may also be overworked. It is probable that by the action of the brain there is a disorganization, to some extent, of its substance, as there is in the muscles by their action. There is evidently some physical state of the brain, induced by too prolonged activity, which unfits it for longer continued effort until time has been given for reparation. This state is indicated by a disposition to knit the brows, more or less of pain in the head, and sense of fatigue. These are intimations from our constitution that rest is necessary and ought not to be disregarded. The too ambitious student, or the too eager business man who disregards these indications, will inevitably suffer the penalty in later years.

To defer this period of weariness, resort is not unfrequently had to artificial stimulants; and they may have this effect, but it is an obvious disregard of a natural warning of the exhausted condition of the system; to silence the warning of danger while the danger is not only present but increasing, must be both unwise and unsafe.

101. The exercise of the brain depends not merely upon the will. There must be general physical health and the

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physical employment. To limit education to the last would be analogous to training an individual to the intricate processes of a difficult trade, when he has not general muscular power enough to make his skill of any avail. The danger is very great, to young men in this country, of hastening too rapidly from general study to professional study. They always regret, in later life, that the foundations of their education were so slender, but the regrets often come when it is too late to apply a remedy.

[34] Certain teachers who have been remarkably successful, have owed their success to the tenacity with which they insisted upon frequent repetition of lessons, review upon review, till the leading principles of a branch of study are ground into the mind, so that they can never be forgotten.

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100. To what danger is the brain liable? What effect does activity of the brain produce in the brain? How is this state indicated? How may this period of weariness be deferred? Why should it not be?

101. What besides the will does the exercise of the brain depend upon? Why observance of those conditions by which general health is preserved. Special importance is, however, to be attached to the preparation of the blood, of which a much larger amount is sent to the brain, in proportion to its size, than to any other organ. For if the blood is impure it operates directly in proportion to the extent of the impurity, to bring on inactivity of the brain, and finally utter prostration and stupor. The preparation of the blood depends upon its being properly subjected to the action of oxygen in the lungs, that is, it depends upon the quantity and purity of the air we breathe. Hence, sleeping-rooms, school-houses, and workshops should, wherever it is possible, be large, and, in all cases, well ventilated. The subject of proper ventilation should be specially attended to in churches and other rooms intended for the accommodation of large audiences.

102. Cases occur in which the brain has a naturally excessive activity. If this is not of itself disease, it is always liable to terminate in disease. Children of more than ordinary capacity, especially if there is an obvious precocity of intellect, should not be stimulated to exertion, but should be held to some extent in check, and their attention should be turned, not, however, in such a way as to attract the notice of the child and make him aware of the purpose, to a large amount of physical effort, and in the open air. This is more important, because this predominating development and activity of the brain is most frequently found in children of a generally weak physical organization and of scrofulous tendencies.

103. The successful intellectual activity of the brain

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is pure blood necessary? What does the proper preparation of the blood depend upon? What practical rules does this suggest?

102. Can the brain have an activity too great to consist with health? What caution does this suggest?

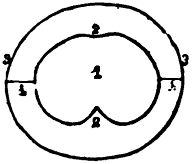
103. What is the last condition of the proper exercise of the brain?

depends in a great measure on the predominant emotions. No person can think vigorously and reliably with a habitually desponding and melancholy temperament. Such a state, if prolonged, is a diseased one, and is to be treated as such. Our Creator has established a generally hopeful tendency in the healthy mind. It is only when buoyant emotions are prevalent that the brain can be active, without leading to morbid, unsocial, morose, and perhaps insane condition of the mind.

Section II.—The Spinal Cord.

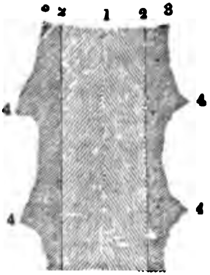
104. The spinal cord is the continuation of the medulla oblongata from the magnum foramen to the sacrum. It is divided by deep fissures in front and behind (2, 2 Fig. 63), into right and left halves, and by slight depressions on the sides, into anterior and posterior portions. The central

Fig. 63.



1 The spinal cord. 2, 2 The depressions on the front and back sides. 3, 3 The spinal canal. 4, 4 The membranes extending to the sides of the canal by which the cord is supported.

Fig. 64.



1 The spinal cord. 2, 2 The pia mater. 3, 3 The ligaments by which the spinal cord is retained in its place. 4, 4 Points by which the ligaments are attached to the walls of the spinal canal.

Section II.—**104.** Describe the position of the spinal cord. Its divisions. Its composition. Its membranes. The means by which it is retained in its place.

portion is composed of gray substance (see Fig. 62), as in the medulla oblongata, and the exterior of white substance. The dura mater and arachnoid membrane form a lining to the spinal canal. The pia mater forms a sheath which incloses the spinal cord. This cord is smaller than the canal in which it is inclosed. The space between the cord and the sides of the canal is filled with a fluid secretion from the arachnoid membrane, and the cord is retained in its position by folds of the pia mater (3, 3 Fig. 64), which are prolonged at points (4, 4), so as to be attached to the sides of the spinal canal.

105. We may now inquire more fully into the functions of the white and gray parts of the nervous system. 1st, **the white substance** It is fibrous in appearance, and the fibres are found to be minute tubes, which are regarded as channels of communication from the points where they originate to the points where they terminate. One class of these tubes is so constituted as to be acted upon only at the extremity most remote from the brain. They receive impressions from light, heat, vibrations, etc., and carry these impressions to the brain. They are called **afferent nerves.** Another class of nerves is acted upon only at the extremity which is in the brain or some other nervous centre. They carry outward to the muscles the impressions of volition, and thus produce the several motions of the body. They are called **efferent nerves.** But in both cases they are mere carriers.

106. These tubes of white substance escaping from a nervous centre are continuous in the nerves throughout

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105. What is the structure of the white substance? What is its function? What is the peculiarity of the afferent nerves? What of the efferent nerves?

106. Does a single nerve ever, by its branches, communicate with two or more nervous centres? How are the nervous centres connected? Give instances.

their whole extent; that is, they do not receive or give off branches. A tube traced backward from a given point of the finger is a single tube till it reaches its nervous centre. But the several parts of these nervous centres are united by a very abundant amount of these fibres of communication. Thus the white substance of the two hemispheres is united by the corpus collosum. The white substance in the halves of the cerebellum is united by the cross fibres of the pons varolii (Fig. 58, *a*). A part of the fibres of the spinal cord cross at the magnum foramen, so that both hemispheres and both parts of the cerebellum are connected with both halves of the spinal cord. The great sympathetic we shall find connected, in like manner, with all of the other parts of the nervous system.

107. Secondly, **the gray substance.** It consists mostly of cells, which seem to be undergoing constant change. It is the source or the repository of all the power of the system.

In the hemispheres it is the organ of all thought, whether manifested in memory, reasoning, intuition, volition, or motion—the white fibres receiving from it impressions which they distribute as may be required.

It is also the recipient of all impressions which the afferent nerves convey. In this substance, therefore, all sensation takes place, all knowledge of the external world is produced.

108. Experiments seem to indicate that the function of the gray substance of the cerebellum is in regulating voluntary motions. It does not produce motion, but it adjusts it, as in the complicated acts of balancing the body in walking, the movements of skill in penmanship and

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107. What is the function of the gray substance? What is its function in the hemispheres of the cerebrum?

108. What is its function in the cerebellum?

other arts, and the control of the muscular movements upon which the modifications of voice depend.

109. The gray substance of the medulla oblongata furnishes the involuntary force upon which the movements of respiration and circulation depend The gray substance of the spinal cord determines the involuntary motions of the body generally. Thus the medulla and spinal cord are independent nervous centres, and the white substance transmits the power thus furnished. But it is only a portion of the white fibres that are thus used Others go to the brain, and thus establish relations between the centre of intellect and other parts of the body.[35]

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[35] If the hand or foot be irritated, an impression is conveyed by the sensory nerve to the spinal cord, and immediately the corresponding motor nerve communicates a convulsive movement to the corresponding muscles. Hence the motion is called *reflex motion*. It depends on the spinal cord alone, for if this cord be divided both above and below the origin of these nerves, the reflex motions are still produced. The movements of respiration, the action of the heart, and the involuntary motions generally, are of this reflex kind.

The discovery of this independent function of each portion of the spinal cord establishes a close resemblance between it and the ganglionic system of the lower orders of the animal kingdom. If the anterior and posterior parts of a centipede be cut off, it will still continue to crawl, the ganglion corresponding with each pair of legs acting as an independent nervous centre to give them motion. But the motion in this case will be invariably in a straight line, regardless of obstacles. The same insect has in the head a ganglion larger than the rest, called the cephalic ganglion, with which every pair of legs also communicates ; and when this communication exists, the animal will move by the reflex action of the other ganglia, and yet it will avoid obstacles. Hence we must regard this cephalic ganglia as the seat of intelligence, though it may be of a very low order.

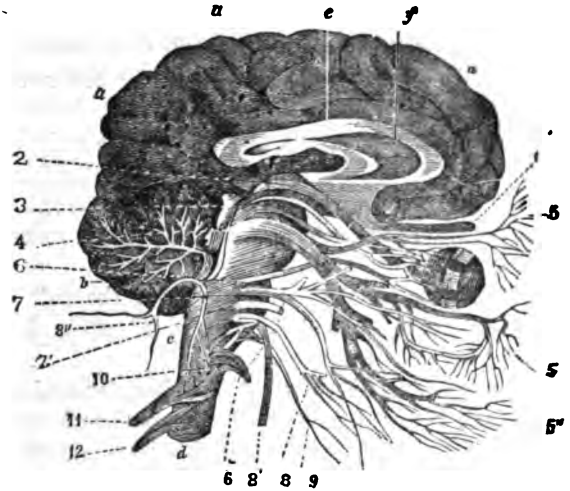
We should then conclude that the functions of mere animal life reside in the spinal cord, and that all mental functions belong to the cephalic ganglion. This is true in all the grades of animal life. Such is the

109. What is its function in the medulla? What in the spinal cord?

Section III.—The Nerves.

110. The nerves are small white cords which pass out in pairs from the brain and spinal cord, and spread themselves through every part of the body. Like the spinal cord,

Fig. 65.



A longitudinal and vertical section of the Brain, and a side view of the Medulla Oblongata. *a a a* The cerebrum. *b* The cerebellum. *c d* The spinal cord. The medulla oblongata is its extension upward. *e* The corpus callosum. 1 The olfactory nerve. 2 The optic nerve. 3 The motor oculi. 4 The trochlearis. 5, 5', 5'' The trigemini. 6 The abductor oculi. 7' The auditory nerve. 7 The facial nerve. 8 The glosso pharyngial nerve. 8' The par vagum. 8'' The spinal accessory nerve. 9 The hypo-glossal nerve. 10, 11, 12 Spinal nerves.

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structure in the worm, the butterfly, the honey-bee, and the spider. Such is also the structure in the vertebrate animal. Even in this class, in its least development, there is no brain, scarcely even a cephalic ganglion. But as the animal rises higher in the scale of intelligence. the cephalic ganglion becomes larger, separate parts become distinguishable as the animal comes to possess a separate and peculiar character, and finally we have in man the largest brain and the fullest mental powers.

***Section III.*—110.** Describe the nerves. What is the first class of nerves?

they are composed of gray and white matter, and are inclosed in sheaths, which are formed by extension of the three membranes which inclose the brain.

I. *The Cranial Nerves.*

111. There are nine pairs of nerves which pass out through the cranium:

(*a*) **The olfactory** (1, Fig. 65), arises from the fissure between the anterior and middle lobes of the brain. It passes out, by several fasciculi, through the perforations in the ethmoid bone, and is distributed to the different parts of the nose.

(*b*) **The optic nerve** (2), arises from the middle lobe, and enters the orbit of the eye through the optic foramen.

(*c*) **The motor oculi** (3), arises just in front of the pons varolii, enters the orbit, and is distributed to most of the muscles of the eye-ball.

(*d*) **The trochlearis** (4), arises from the side of the pons varolii, enters the orbit, and is spent upon the superior oblique muscle of the eye.

(*e*) **The trigemini** (5, 5′, 5″), arises from the pons varolii, a little below the origin of the trochlearis, by three roots, and passes out of the cranium by three branches, and is distributed to the ball of the eye, to the eyelids, to the interior of the nose, to the gums and teeth of the upper and lower jaws, to the tongue, and to the ear.

(*f*) **The abductor oculi** (6), arises from the anterior portion of the medulla oblongata, below the pons varolii, passes to the orbit, and is spent on the external straight muscle.

(*g*) This pair consists of two nerves,[36] **the auditory**

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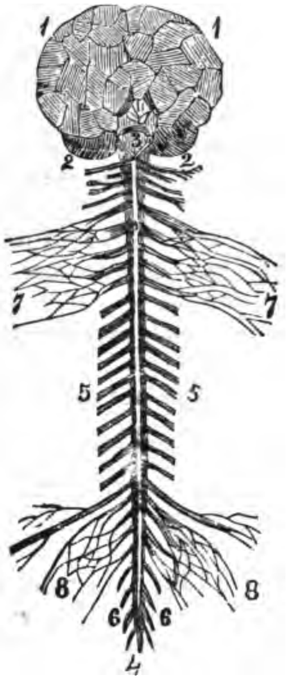
[36] There is no reason why this pair should not be regarded as two pairs, except the fact that they escape from the cranium together. The

111. Describe the origin and distribution of the olfactory nerve. The optic nerve, etc. What is the second class of nerves?

and facial (7, 7′), which arise from the medulla below the pons varolii. The auditory portion passes through the temporal bone to the interior of the ear, where it terminates. The facial portion winds through the cavities of the temporal bones till it escapes in front of the mastoid process. It is distributed to the face.

(*h*) The eighth pair is composed of three nerves (8, 8′, 8″), **the glosso-pharyngeal,** which arises from the middle of the posterior part of the medulla oblongata; the *par vagum,* which arises a little below the preceding; and the *spinal accessory,* which arises from the posterior part of the spinal cord for two or three inches below the magnum foramen, and passes up into the cranium. These three nerves pass out of the cranium together. The first branch is distributed to

Fig. 66.



1, 1 The cerebrum. 2, 2 The cerebellum. 3 The medulla oblongata. 3, 4 The spinal cord. 5 The dorsal nerves. 6 The sacral nerves. 7 The axillary plexus. 8 The lumbar plexus.

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auditory and facial portions are distinct in their origin, as will be seen from the figure. They are different in structure, one being a dense, firm nerve, and the other very soft. They are entirely different in their distribution and functions. One goes to the face, and the other to the ear. One is a nerve of sensation, and the other of motion. The same might be said generally of the three portions of the eighth pair. Accordingly, many anatomists represent the cranial nerves as consisting of twelve, instead of nine pairs.

the tongue and pharynx, the second to the lungs and stomach, and the third to the muscles of the neck.

(*i*) **The hypo-glossus** (9) arises from the lower anterior portion of the medulla oblongata, and is spent upon the tongue.

II. *The Spinal Nerves.*

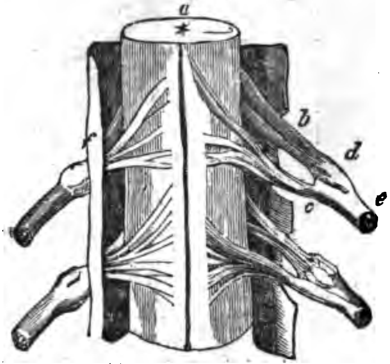
112. There are thirty pairs of nerves which arise from the spinal cord (Fig. 66).

(*a*) **The sub-occipital nerve** escapes from the spinal cord between the occipital bone and the atlas.

(*b*) **The cervical nerves,** of which there are seven pairs, escape through the intervertebral foramina, below each cervical vertebra.

(*c*) **The dorsal nerves,** of which there are twelve pairs, come out from the spinal cord below each dorsal vertebra.

Fig. 67.



a The spinal cord. *b c* The two roots of which each spinal nerve is formed. *d* The ganglion formed on each posterior root. *e* The nerve after the junction of the two roots.

(*d*) **The lumbar nerves,** five pairs, escape below each lumbar vertebra.

(*e*) **The sacral nerves,** of which there are five and often six pairs, escape through the foramina of the sacrum.

113. Each of the spinal nerves arises from the spinal cord by two roots (*b*, *c*, Fig. 67,) one of which comes from the

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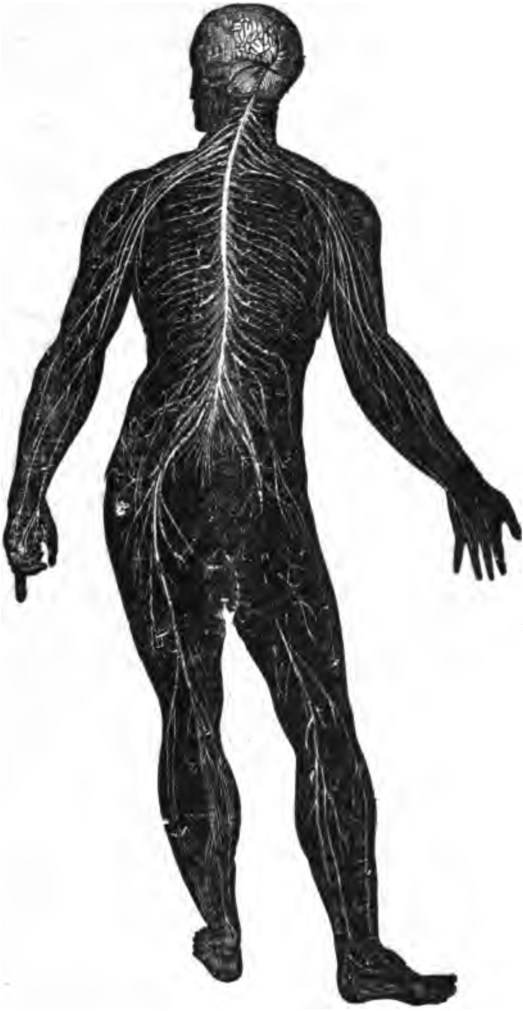
112. How many pairs of spinal nerves are there? Give the origin and each division of these nerves.

113. How do these nerves arise from the spinal cord? What is the peculiarity of each posterior root? How is the whole nerve finally formed?

Fig. 68.



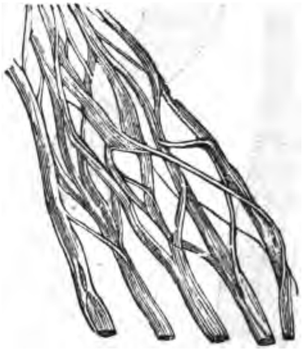
General distribution of the nerves of the system.

anterior and the other from the posterior portion. The posterior root, *b*, forms a ganglion; that is, an enlargement of the nerve into an oval form, *d*, just after the nerve escapes from the intervertebral foramen. At a little distance from the ganglion the two roots unite to form one nerve, *e*, and every branch of the nerve in its distribution through the body contains fibres of each root.

114. The sub-occipital nerve and the first three cervical are distributed to the muscles of the neck and the integuments of the head.

The four inferior cervical and the first dorsal nerves unite to form the axillary plexus (7, Fig. 66), (a network of veins, Fig. 69, produced by division of nerves into several branches, and their crossing, recrossing, and interlacement), from which the nerves of the upper extremities proceed.

Fig. 69



A plexus or network of nerves.

All the dorsal nerves (5), except the first, are distributed to the muscles and integuments of the back, thorax, and abdomen.

The lumbar nerves (8) form the lumbar plexus which rests on the spine in the lower part of the abdomen. This plexus furnishes the nerves to the muscles and other parts contained within the pelvis.

The sacral nerves form the sciatic plexus, which is situ-

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114. What are the nerves which supply the neck and head? How are the upper extremities supplied? What is a plexus? What is the distribution of the dorsal nerves? What of the lumbar nerves? How are the lower extremities supplied?

ated below the lumbar plexus and within the pelvis. It furnishes the nerves to the lower extremities.

115. Such is the general distribution of the nerves of the head and spine; but throughout the system they interchange filaments so frequently, that a common sympathy is established between all parts of the body.

III. *The Great Sympathetic Nerve.*

116. This nerve (Fig. 70) consists principally of a chain of ganglions, situated on each side of the spinal column in the neck, thorax, abdomen, and pelvis. Three of these ganglions are placed on the cervical vertebræ, twelve on the dorsal, five on the lumbar, and generally three or four on the sacrum. The ganglions are connected together by short nerves. Each spinal and several cranial nerves send filaments to the ganglions. It is then a system of ganglions connected together and to the general nervous centre of the body, at a large number of points, by nerves; and from it arise, at different points, other nerves having peculiar functions, and distributed to the lungs, the heart, the arteries, and to the viscera of the abdomen.

IV. *Functions of the Nerves.*

We have before spoken of the afferent nerves, which are nerves of sensibility, and of the efferent nerves, or nerves of motion. But for our present purpose they may be divided, according to their functions, into four classes.

117. (1.) **The nerves of special sensibility**. These are the olfactory nerve, which conveys only the impression of odors; the optic, which conveys only impressions of

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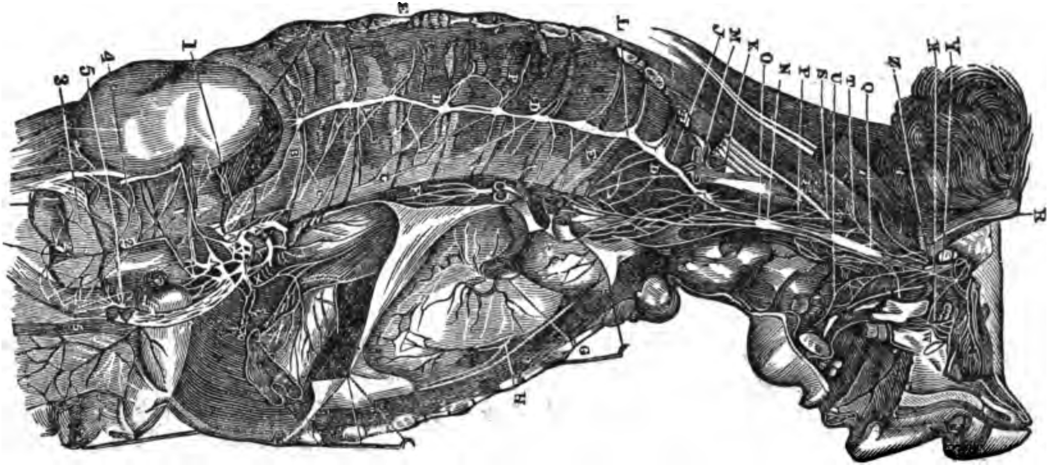
115. What is the effect of the interchange of filaments between the nerves?

116. Describe the great sympathetic nerve. What is the distribution of the nerves coming from the great sympathetic? Into how many classes are the nerves divided?

117. What are the nerves of special sensibility? How are those sensations accounted for, when there is no external object corresponding with the sensation?

Fig. 70.



The system of the Great Sympathetic Nerve. A A The semi-lunar ganglion and solar plexus, situated behind the stomach. D D Thoracic ganglia. P O E External and internal nervous filaments. G H The coronary plexuses, situated on the heart. I The lower cervical ganglion. N The middle cervical ganglion. Q The upper cervical ganglion. 1 The renal plexus, situated on the kidneys. 2, 2 Lumbar ganglia. 3, 4 Nervous filament from them. 5, 5 The aortic plexus.

light; the lingual branch of the fifth pair, which conveys only impressions of taste; and the auditory, which conveys no other impressions than those of sound.

Under peculiar circumstances these nerves may be affected by other means than those which ordinarily excite them. Thus, there may be a sensation of light occasioned by a galvanic shock.[37] There may be a sensation of distant thunder, or of ringing of bells, or music, occasioned by a diseased state of the head. It is to be supposed in such cases that the nerve, by unusual means, is brought into the same state into which it would be brought by the presence of its ordinary stimulus. The inference then is, not that the nerve is insensible to the influence of other physical agents, but that by whatever agent it may be acted upon, it can convey to the brain only particular impressions, those for which it is specially fitted.

118. (2.) **The nerves of general sensibility.** The fifth pair, or trigemini, with the exception of the lingual branch, is the nerve of general sensibility to the organs of the senses. It cannot convey the impression of odors, light, taste, or sound. Its action is, however, necessary in producing these impressions; for when it is severed or injured, the nerves of special sensibility lose the power of conveying their appropriate impressions.

119. The posterior roots of the spinal nerves are the nerves of general sensibility of the body. These nerves convey the general sensations of pressure, temperature, form, weight, etc.[38]

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[37] For a similar reason, a person who has fallen upon his head will describe the sensation by saying that he "saw stars."

[38] The mind always refers the sensations produced by these nerves to

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118. What is the second class of nerves? Describe the functions of the fifth pair.

119. What are the spinal nerves of general sensibility? What are the func-

There is another class of sensations referable probably to these nerves, and yet not with certainty. They imply particular conditions of the body, and are in many cases of the nature of overseers to notify us of our wants. Among these sensations are those of hunger, thirst, nausea, fatigue, and several others.

Besides these definite sensations, there is an indistinct and diffused sensibility depending upon the nerves. They may be so active as to produce extreme excitability, or they may be so inactive as scarcely to convey to the mind the impression of the continuance of life, an absence of sensitive enjoyment. The state intermediate between these two is the only one consistent with health and efficiency; one in which there is a feebly observed but constant communication between the surface of the body and the mind —such an amount of sensation as to result in the general feeling of satisfaction and contentment.

120. These nerves also act the part of sentinels. We have seen that they are most abundantly supplied at the surface of the body, and it is from without that danger is mostly to come. The pain which they cause when the surface is injured is both the warning of our danger and the motive to attend to it. These sentinels are in every part of the surface of the body, so that the point of a needle cannot be put down where they will not be found,

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the extremity of the nerves. Thus, a person whose limb has been amputated will, when the remaining part of the nerve is affected, refer the sensation of pleasure or pain to the part in which those nerves terminated while the limb existed.

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tions of these nerves? What sensations are referred provisionally to them? Describe the diffused sensibility referable to them.

120 How do these nerves act as sentinels? Why are they most abundant at the surface? In what respects are they an evil? How is this evil overbalanced by advantage? Is the evil as great as is generally supposed? How may it be overcome?

and their warning is instantaneous, authoritative, and generally proportioned to the danger. To realize their importance, we have only to reflect how constantly and seriously we should be exposed to injury from burns, wounds, bruises, etc., if we were deprived of this kind of warning.

It is true that these nerves may also sometimes be very much in our way. Thus, in case of amputation or other surgical operation, much suffering necessarily results from the sensitiveness of these nerves, without, so far as we can see, any direct advantage. But, in the first place, the sensitiveness from which we suffer under such circumstances has been the means of preventing the necessity of such operations more frequently; in the second place, this high degree of sensitiveness exists only at the surface, so that such operations are less painful than we are accustomed to suppose—the bones, muscles, and other deep parts being very indifferently supplied with sensitive nerves; and in the third place, the medical art has furnished the means of suspending, temporarily, this sensitiveness.

121. These nerves are not essential to merely animal life. They may be severed so that the individual will be insensible to any form of external injury, and not even know whether his limbs are connected with his body or not, except as he learns it by the sense of sight, while he may yet possess perfectly the power of motion, and while the appetite, digestion, and general health are unimpaired. Cases have occurred which justify these statements, and they have been proved by experiments on the lower animals.[39]

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[39] There was a person in London, some years since, in whom on one side of the body the nerves of sensation alone were perfect, and on the other side the motor nerves, and those alone, were capable of performing their function.

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121. Are these nerves absolutely essential to animal life?

122. There are some peculiar adaptations in these nerves to the kind of sensitiveness required. Thus, the exposed part of the eye is extremely sensitive to particles of dust, which, if allowed to collect, would soon destroy its transparency; but sensitiveness to violent injury would answer no good end, and accordingly hard pressure upon the eye —and even piercing it, in operation for cataract—is not very painful. In like manner, the muscles of the iris are sensitive only to light; nor are they sensitive to light thrown upon them, but to light admitted into the eye, the object being to graduate the quantity of light which the eye receives. In accordance with the same principle, the brain, which could receive no protection by a high degree of sensitiveness, is nearly insensible, so that considerable portions of it have been, in some cases, removed without producing pain.

There is another adaptation seen in the sensitiveness varying with the need for it. The bones, cartilages, tendons, etc., have ordinarily but little sensitiveness, but when inflammation takes place in them they become painful in the extreme. It is only when they are in a diseased condition that susceptibility to pain could do us any good. Its severity is proportioned to the urgency of the case, for these deep-seated inflammations are always of a more serious character than the superficial ones. On the same principle any part becomes specially sensitive under inflammation, in order to compel us to care for it while it needs care.

Of a somewhat similar character is the relation of the nerves of sensation to those of motion, when under the

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122. Give instances in which the nerve, by the kind of sensation that it can convey, is adapted to the wants of the part to which it is distributed. Show how the variations of sensitiveness are an adaptation to the wants of the system. How are the different capabilities of the nerves of sensation and of motion to resist the effects of cold a provision for our protection?

influence of intense cold. When any part is in danger of freezing, the sensitive nerves occasion severe pain, and we are thus admonished of our danger. But while the nerves of motion still retain their power, and there is, therefore, a possibility of making farther efforts to secure our safety, the sensitive nerves lose their power. The cessation of the pain frees us from the continuance of suffering, while by the change it again warns us that there is still a last chance of safety.

123. (3.) **The nerves of voluntary motion.** Four pairs of the cranial nerves are connected with the voluntary motions. The motor oculi, the trochlearis, and the abductor oculi govern the motions of the eye, and the hypoglossus governs the motions of the tongue.

The anterior roots of the spinal nerves are the source of all the other voluntary motions of the system. Although there is this distinction of functions between the anterior and posterior roots of the spinal nerves, yet they sustain a most intimate relation to each other. The anterior roots are the means of communication between the organ of the mind and the muscles, by which motions are produced, while the posterior roots are the means of communication between the muscles and the organ of the mind. A common form of expressing this relation is, that the nerves of motion carry the mandates of the will to the muscles, and the nerves of sensation convey back to the mind a knowledge of the condition of the muscle; they inform the mind whether or not its mandates have been obeyed. Thus the circuit is completed when it commences at the brain. At other times it may be regarded as originating

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123. What is the third class of nerves? What are the cranial nerves of this division, and what motions do they control? What are the spinal nerves of voluntary motion? Describe the relation between the nerves of sensation and those of motion.

in some circumstance exterior to the body, a knowledge of which is conveyed to the mind by the nerves of general or special sensibility, and the mind controls the muscular action as the knowledge communicated may render desirable.

124. (4.) The nerves of involuntary motion. The nerves which control the involuntary motions of the system are the facial portion of the seventh pair, the eighth pair, and the great sympathetic nerve.

The facial nerve is the one upon which depends the expression of emotions in the face, such as joy, grief, fear, anger, revenge, etc. These motions of expression may, by long practice, be brought, to some extent, under the control of the will, so that when the emotions exist they shall not be depicted in the face, or so that there may be expression of them in the face when the emotions do not exist.[40] But

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[40] It has, however, *been said* that some actors have obtained so complete control over this nerve, that they could not only give the expression of any emotion at pleasure, but that, to some extent, they could represent one class of emotions by one side of the face, and another class, at the same time, by the opposite side.

The aborigines of this country have great power, not in giving the expression of emotions which do not exist, but in suppressing the expression of emotions which they do feel. Hence the comparison, "impassible as an Indian." They are said to have cultivated this power from the desire to prevent Europeans from thus learning their wishes and taking advantage of them.

The unwillingness which many persons feel to exhibit their emotions is not natural, and can scarcely be justified. This susceptibility was given us for wise purposes. Why should we be unwilling to show proper emotions? and why should we not allow upon ourselves this check against

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124. What is the fourth class of nerves? What nerves belong to this class? What are the functions of the facial nerve? To what extent may these motions become voluntary? What easier way to avoid or exhibit the expression of emotions? What use do actors make of this fact? What is the distribution and office of each nerve of the eighth pair? To what extent is the great sympathetic connected with the other portions of the nervous system? With what are its branches associated? What is their distribution and office?

this control is generally very imperfect. It is much easier to control the emotions than to control the natural expression of them when they arise. Hence it is that actors strive to awaken the emotions in their own mind which they wish to represent, and allow the natural expression of them in the countenance, rather than attempt to give the expression of them when they do not exist.

The three parts of the eighth pair of nerves have separate functions. The glosso-pharyngeal directs the motions of deglutition; the par vagum seems to act in conjunction with the great sympathetic; and the spinal accessory directs those involuntary motions of the neck and shoulders which take place in coughing or sneezing.

We have seen that the great sympathetic is intimately associated with the other portions of the nervous system by numerous filaments It, however, seems to be, to a great extent, a system of independent nervous influence. The nerves which it gives off become associated with the branches of the par vagum, and together they form sheaths of nervous matter around the arteries; they also collect in plexuses on the heart, the diaphragm, the stomach, the kidneys, etc., to all which organs they supply the requisite nervous influence.[41]

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improper emotions? This involuntary manifestation of emotions is one of the most pleasing elements of social life, while it is also a safeguard against injury, because it is the natural warning which excited passion always gives. We are most charmed by those whose emotions are strongly painted in the face, but we are always suspicious of the person who can keep his emotions to himself.

[41] A fifth class of nerves is generally introduced, which preside over the respiratory movements. As this motion is both voluntary and involuntary, it is supplied with both kinds of nerves. The involuntary are always active, yet the voluntary nerves can, for a short time, control their action. Sir Charles Bell, who first proposed this as a distinct division, also noticed a peculiarity in the origin of these nerves, namely, that they take

CHAPTER II.—OF THE ORGANS OF THE SENSES.

Section I.—The Sense of Sight.

125. The structure of the organ of sight may be considered in reference to its external and internal parts. 1st, **the external parts. The orbit** of the eye is a deep cavity, situated in the upper part of the face and directly under the anterior lobe of the brain. The ball of the eye is lodged in the orbit, but does not entirely fill it. The space between the ball and the orbit is filled with muscles and adipose substance. **The muscles** and their action have been elsewhere described. The adipose substance serves to fill up the irregularities of the orbit and as a cushion for the ball.

The front part of the eye, so much as can be seen by lifting the lid, is covered by a very delicate membrane, **the conjunctiva**, which possesses extreme sensibility to the presence of minute foreign particles upon the surface, and is therefore an important protection to the eye in maintaining its transparency. The eye is farther protected by **the lids**, at the edges of which, as a curtain, are attached cartilages, which keep the lids in form, and serve for the attachment of the muscles to open and close them.

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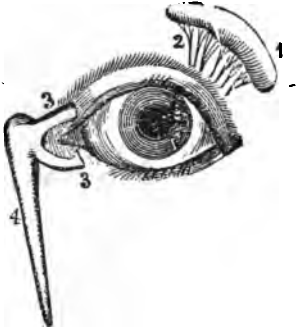
their rise in the upper part of the spinal cord from a lateral portion, intermediate between the voluntary and involuntary portions of the cord, as if the two had here blended into a common tract, for the purpose of giving to the nerves from this portion this double character.

Chapter II. ***Section I.*—125**. What are the external parts of the eye? Describe the orbit. What besides the ball of the eye does it contain? Describe the muscles of the eye. (See Appendix.) What is the conjunctiva? What is its office? Describe the eyelids. By what muscle is the upper lid raised? By what muscle is the eye closed? Describe the lachrymal gland. How is the lachrymal secretion useful? How is it disposed of? What circumstances tend to increase this secretion?

The lachrymal gland (1, Fig. 71), about the size of an almond, lies in the upper outer part of the orbit, and furnishes, by several ducts (2), a fluid secretion which is spread over the eye every few seconds by the motion of the lids. Its object is to prevent friction by the motion of the lid, to keep the surface moist, and to wash off whatever may have fallen upon it. This fluid collects finally at the inner corner of the eye, and is taken up by two capillary tubes, the puncta lachrymalia (3, 3), and by them conveyed to the lachrymal duct (4), and is thence discharged into the nose.[42] The current of air passing through the nostrils will generally cause the evaporation of whatever moisture is thus thrown into the nose. In a diseased condition of the eye, or from particular states of mind,[43] this secretion may be increased till the current of air does not take it up, or even so much that it escapes as tears outside of the eye.

Fig. 71.



1 The lachrymal gland. 2 The ducts by which its secretions are conveyed to the eye. 3, 3 The puncta lachrymalia. 4 The lachrymal duct.

126. 2d. **The internal parts of the eye.** The ball

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[42] The lachrymal duct is lined with a continuation of the membrane of the nose, and in case of colds, this membrane is liable to become thickened so much as to fill the duct. When it becomes permanently filled, a small metallic tube may be inserted, and is found to answer the purpose perfectly. When this is not done the eye becomes inflamed, and the sight is in danger of being lost.

[43] This secretion is increased when any extraneous matter gets into the eye, for the purpose of washing it out. Why it should be increased by mental emotions we do not know, yet such is the fact, and it is certain that, in some way, it does tend to mitigate the crushing influence of deep grief.

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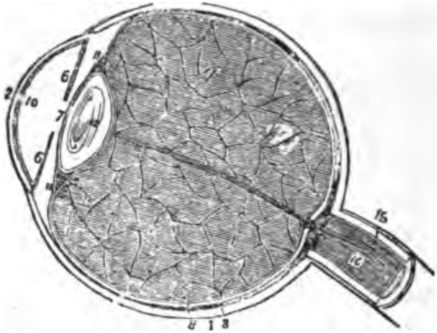
126. What is the shape of the eye-ball? By how many layers or coats is the of the eye is nearly a perfect sphere, with the exception of the protuberant part (2, Fig. 72) in front, which is a small segment of a smaller sphere than the body of the ball. The ball is supported in its form by several membraneous layers.

Fig. 72



Section of the Eye. 1 The sclerotic coat. 2 The cornea. 3 The choroid coat. 6, 6 The iris. 7 The pupil. 8 The retina. 9 The ciliary processes from the choroid coat by which the crystalline lens is supported. 10 The anterior chamber of the eye. 11 The posterior chamber. 12 The crystalline lens. 13 The vitreous humor. 15 The optic nerve. 16 The artery of the interior of the eye.

The outermost is **the sclerotica** (1), a dense, opaque membrane, commonly referred to as the "white of the eye," which forms an entire envelope for the eye, except a circle of about half an inch diameter in front. This space, the protuberant part of the eye, is covered by another membrane, **the cornea**, which may be regarded as a continuation of the sclerotica, and which differs from it principally in being transparent. **The iris** (6) is a small membrane attached to the anterior edge of the sclerotica.

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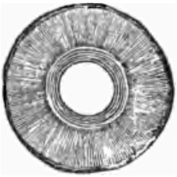
eye surrounded? Describe the sclerotica. The cornea. Describe the iris. What is the pupil? What is the second coat of the eye? In what state is the interior of this coat? What is the use of this pigment? What is the third coat of the eye? Describe the retina.

The circular orifice (7) in the centre is **the pupil.** The iris is composed of circular and radiant muscular fibres (Fig. 73) by which the pupil may be enlarged or contracted, so as to increase or diminish the amount of light admitted into the eye.

Fig. 73.

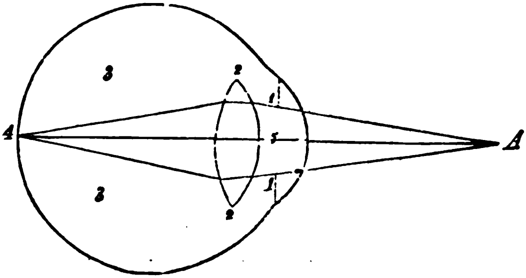


A view of the iris, showing the circular muscular fibres around the pupil, and the radiating fibres reaching to the circumference.

The second envelope is **the choroid coat.** It is within the sclerotica, in contact with it, and is terminated in front by a thickened edge called the ciliary ring. The interior of the choroid coat is covered by a black or very dark pigment, the use of which is to absorb any light which might otherwise be diffused through the eye.[44]

The innermost layer is **the retina.** It is formed by the optic nerve, which, after it passes into the eye, is spread out into a thin, delicate network, lining the whole interior of the eye, and is the seat of vision.

Fig. 74.



A Any point of a variable object from which rays come into the eye through the pupil, 1, 1, are converged principally by the lens 2, 2, and brought to a focus on the retina at 4. 3, 3 The vitreous humor.

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[44] In imitation of this peculiarity of the eye, and to accomplish the same object, it is the uniform practice to blacken the inside of telescopes and other optical instruments.

127. The eye is filled by three transparent substances, the object of which is to concentrate the rays of light which enter the eye. **The vitreous humor** (3, 3, Fig. 74) is in the posterior part of the ball, and occupies about four-fifths of its cavity. It is very similar in appearance to the white of an egg, but it is more viscid. **The aqueous humor** is a perfectly limpid liquid, situated in the front part of the ball. The iris is suspended in this humor, and divides it into anterior and posterior chambers (10, 11 Fig. 72). **The crystalline body** (12) is a solid double-convex lens, situated between the aqueous and vitreous humors, and is suspended in its position by filaments from the ciliary ring. This lens increases in density from the circumference to the centre, and the convexity of the posterior is greater than that of the anterior face.

128. Light is the only appropriate stimulus of the nerves of sight. If we consider separately the rays which come from a single point of a visible object, we shall see that they are necessarily divergent. Those which enter the eye we may regard as forming a cone, of which the point of origin (*A*, Fig. 74) is the apex, and the area of the pupil (1, 1) is the base. The object of the refracting media[46] of the eye is to bring all the rays of this cone to a point at 4. The cornea first acts upon the rays to diminish their divergence. The aqueous humor slightly increases this divergence, but not enough to overcome the effect of the cornea. In this state those rays which pass through

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[46] This is not the place to discuss the properties of light, and we must assume that the general laws of the refraction of light are understood.

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127. With what are these coats filled? Describe the vitreous humor. The aqueous humor. How is it divided? Describe the crystalline lens.

128. What is the physical agent in producing vision? Why are the rays of light divergent as they enter the eye? What is the object of the refracting media of the eye? What is the effect of each portion, and what is the final effect? When the rays of light are brought to a focus on the retina, what is the effect?

the pupil and fall upon the crystalline lens (2, 2) are made to converge, and the convergence is so far increased by the vitreous humor (3, 3), that when they reach the retina they all fall upon the same point (4). The retina, which is an expansion of the optic nerve, and in which this point is situated, communicating directly with the brain, the sensation of sight at once exists in the mind. How the focus of light on the retina produces sensation we can form no idea whatever; we must receive it as an ultimate fact.[46]

It is a primary law of vision that any point of a visible object is seen in the direction of a straight line from its focus (4, Fig. 74) *on the retina, through the centre* (5) *of the pupil.* All the points of a visible object from which light can reach the eye will be represented by corresponding points in the eye; and these points on the retina, which, taken together, constitute a perfect image of the object, will, when seen together, convey to the mind a distinct idea of the object.

It is the object of this sense to convey directly only ideas of the color of objects and their direction from us, and of solidity; but indirectly it becomes the most impor-

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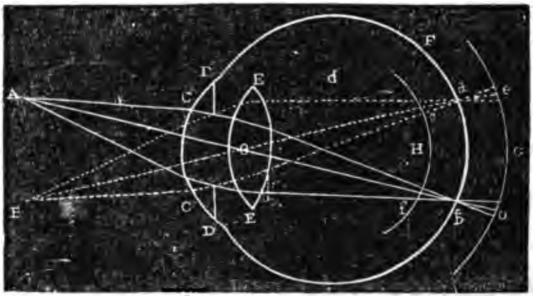
[46] It is important to fix in the mind, that we can form no idea how sensations are produced. We can trace the successive changes up to the brain, but we find nothing which would lead us to expect the result. When we examine the result, we see no reason why it should have been produced by the light, nor why light should be necessary. The study of nature, in every department, is continually bringing us to these limits of human power, compelling us to feel that these are not only unexplained facts, but are, in their nature, inexplicable to beings of our limited capacities, and leading us to recognize, in all our investigations, the existence everywhere of an efficient Cause, which can be only God.

How does it produce this effect? What is the direction in which a visible point is seen? If we see only points, how do we see any object? What ideas does the sense of sight give us directly? What does it give indirectly?

tant of the senses, by giving us the ideas of form, magnitude, distance, and motion.

129. It is obvious that the highest points of an object (A, Fig. 75) will be represented on the retina by the lowest points, *b*, and the lowest points of the object by the highest points on the retina—that is, the pencils of light will cross at the pupil, and the image will be inverted. But the mind does not see the image any more than it does the object. Each point in the retina upon which the image is placed conveys to the mind an idea of its true position as referred to the object. The point *b* is recognized to be at A, in accordance with the general law above given; the point *a* at B, and so of every other point; that is, objects are seen erect, and not inverted.

Fig. 75.



A and B Two points of a visible object. The pencil of rays from each point is brought to a separate and perfect focus on the retina, and each point is seen in the direction from *a* or *b* through the centre of the pupil.

130. Each point in one retina has a corresponding point in the other, and these two points sustain by our nature such a relation to each other, that when they are both

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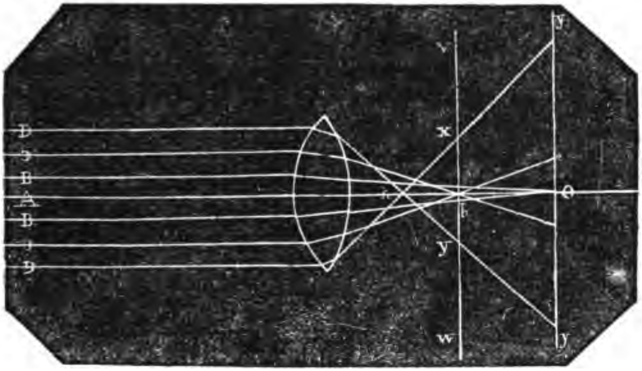
129. Why will the image in the eye be inverted? Why then is not the object seen inverted?

130. Why do we see objects single with two eyes? How may the eye be so affected that we shall see two objects when there is but one?

acted on exactly alike, that is, by the same object, they convey to the mind the impression of but one object; but if, by a slight pressure of one eye from its natural position, we cause the same object to be represented on parts of the retina which are not corresponding parts, we see two objects, though there is but one. We, therefore, see objects single, though seen by both eyes, because they affect corresponding parts in both retinas.

131. As the refraction of a ray of light depends in part on the degree of obliquity with which it falls on the refracting substance, it will be seen that the outermost rays (D D, Fig. 76) which come from a visible object, as they fall upon the lens more obliquely, will be most refracted. If the lens be of uniform density and have a spherical curve, the outer rays will be brought to a focus at *n*, nearer to the lens than those rays which are more central.

Fig. 76.



The ray A O passing through the centre of the lens is not refracted at all. The rays B B are refracted somewhat, and come together at *o*. C C meet at *h*, and D D are the most refracted, and come to a focus at *n*.

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131. What is spherical aberration? How is it corrected in the eye?

This is called **spherical aberration.** To obviate it and bring the focus of all the rays at *h*, the crystalline lens is more dense toward the centre, in order to increase its refracting power upon the more central rays. Besides, the iris cuts off the extreme rays, and allows only those near the centre to enter the lens.[47]

132. There are two circumstances in connection with vision which are subject to constant variation, namely, the distance of the object and the intensity of the light; and the eye has the power of adapting itself to these variations. The amount of light admitted is controlled by the iris. After being in a full light for a short time, the pupil becomes so small by the contraction of its circular fibres, that upon entering a partially closed room we seem to be in utter darkness, so little light does the pupil admit. But very soon the radiant fibres of the iris contract, the pupil enlarges, and enough light is received into the eye to give us distinct vision, though the light of the room remains the same. The object of the iris is to guard the retina from injury by exposure to too intense a light, and hence the muscles of the iris are not directly sensitive to light. It has been proved, by careful experiment, that light thrown upon the iris has no effect to contract the

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[47] An adjustment is also necessary to prevent the effects of chromatic aberration; that is, to prevent the image on the retina being colored, in consequence of the different degrees of refrangibility of rays of light of different colors. This explanation requires a somewhat intimate acquaintance with optical principles. The eye is probably not absolutely achromatic. Whatever correction for this aberration is made, is due to the peculiar combination of solid and fluid lenses in the eye.

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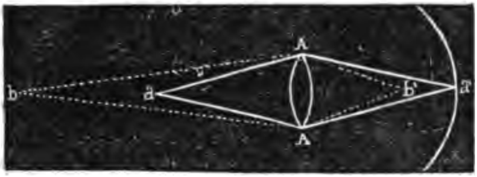
132. What are the two varying circumstances to which the eye must adapt itself? How is the amount of light controlled? Does strong or weak light control the action of the muscular fibres of the iris as it falls upon them? How is this action controlled? Why should the size of the pupil be controlled by the retina?

circular muscles, and the contraction of the radiant muscles is not promoted by screening them from the light. It is the retina itself which, in some unexplained way, reacts upon the iris to effect the contraction and relaxation of its muscles. Thus the control of these muscles is given to the part which they are designed to protect.

133. If rays of light come from two points (a and b, Fig. 77) it is obvious that those which come from the greater distance, *b*, will have less divergence, and will, therefore, come to a focus (at *b'*) nearer the lens than those which have greater divergence. In order that this more distant object be distinctly seen, the retina might be brought forward from *a'* to *b'*; or the refracting power of the lens might be diminished so as to keep the focus still at *a'*. The latter method seems to be adopted. The crystalline lens, in its ordinary condition, is *compressed* by the ciliary processes, as a band around its circumference, and its front is bulged out so that it can sufficiently converge the rays from near objects. When a distant object is looked at, muscular fibres extending from 11, Fig. 72, to the edge of the choroid act on the band of ciliary pro-

Fig. 77.



The rays from *b* which fall upon the lens A A, are necessarily less divergent than those from the nearer point *a*. As they diverge less, they will require less bending to bring them to a focus, or by the same bending they will come to a focus *b'* nearer to the lens than *a'*, the focus of rays from *a*.

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133. Why is an adjustment necessary to see objects distinctly at different distances? How is this adjustment made?

cesses, drawing it slightly away from the lens, which then takes its uncompressed form and becomes flattened; that is, it loses a part of its converging power, just enough so that the less divergent rays from distant objects will come to a focus on the retina. Thus the eye is adapted to distinct vision at varying distances.

134. When both eyes see the same solid object, the right eye must see more of it on the right side, and the left eye more of it on the left side, and yet we are conscious of only one object, but we are conscious of it as a *solid*. The stereoscope is an optical instrument so constructed that we may see at the same time two pictures of a solid body, not exactly alike, but differing from each other just as the images do on the two retinas. The two pictures give us the conception of only one object, but it is not the conception of a picture; that is, it is not the conception of a plane surface, but of a solid body. It seems, then, that we are constituted so as to get, by the use of two eyes, the notion of body, or solidity.

135. There are persons in whose eyes the retina is naturally so far from the lens that only those objects can be distinctly seen that are very near: there are others in which

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[48] Another peculiarity of the eye is, that the retina retains for a very short time the impressions which it receives—not long enough to prevent other impressions from being received almost immediately, but yet enough so that a rapidly moving *point* gives us the conception of a *line*. If the impression on the retina were effaced *instantly* on the discontinuance of the ray of light, we should be left for a moment in the dark every time the light is intercepted by winking.

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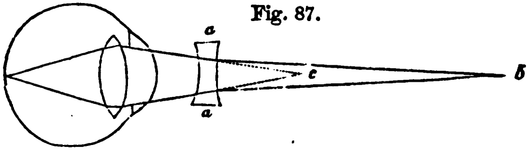
134. How do the images of the same solid body on the two retinas differ? What knowledge does this difference of the image convey to us? How is this illustrated by the stereoscope?

135. What is the form of the eye in short-sighted persons? To remedy this defect, what change must be made in the direction of the rays coming from distant objects? How is this change effected? What is the peculiarity of the eye in long-sightedness? What glasses are required, and why?

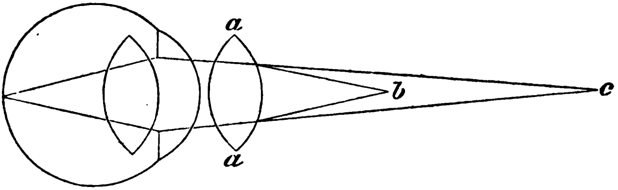
the retina is naturally so near the lens that only very distant objects are distinctly seen. In the first case, that of **short-sightedness**, it is necessary to increase the divergence of the rays; hence concave glasses (Fig. 78) must be used. In case of **long-sightedness**, it is necessary to diminish the divergence when near objects are looked at, and therefore convex glasses (Fig. 79) are required.

Fig. 87.



A cone of rays rendered more divergent by a concave lens, *a a*, to remedy short-sightedness. The rays from a distant object, *b*, enter the eye with the same degree of divergence by the aid of the lens that they would if, without the lens, they came from *c*. If the eye is adapted to see distinctly an object at *c* without the lens, it must also be adapted to distinctly see an object at *b* with the use of the lens.

Fig. 79.



A cone of rays rendered less divergent by a convex lens, *a a*, to remedy long sightedness. The rays from a nearer object, *b*, enter the eye with the same divergence, by the aid of the lens, *a a*, that they would if, without the lens, they came from *c*. The eye can see distinctly the more distant object, *c*, without the lens. It must then be able to see distinctly the nearer object, *b*, by the use of the lens, because the rays enter the eye as if they came from *c*.

136. There is sometimes an imperfection in some of the appendages of the eye, by which they cannot move in such a way that the corresponding parts of the two retinas

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136. In what does squinting consist, and how can it be remedied? In what does looking cross-eyed consist, and how is it to be remedied? Do these defects of the eye produce double vision?

shall be affected by the same object. Sometimes one eye is weaker than the other, and we insensibly turn it toward the inner angle to reduce the amount of light received. The first of these is **squinting**, and the last is **cross-eye.** In both cases there is double vision; the two eyes convey different impressions of the same object. The mind, however, soon accustoms itself to attend to but one of the impressions. By shading the eye and directing attention to its motions, cross-eye may easily be cured. Squinting can be cured only by a surgical operation, and this is not always successful.

137. The sight is improved by practice, like every other organ, but it requires care. There is no other organ more likely to be overtasked. This may be by using it too continuously without rest, or with too strong or too weak a light. Reading at twilight is a very common way of inflicting injury upon the eye. The evil first appears as a slight inflammation. If the cause of injury is removed and rest is allowed, it may generally be cured by frequent bathing of the eye in pure water, as cold as it will bear without pain. Any other eye-waters are generally injurious, and should never be used, unless prescribed by a judicious physician.

The eye is also apt to sympathize with a disordered condition of the general health. When this is the case the health and not the eyes requires attention.

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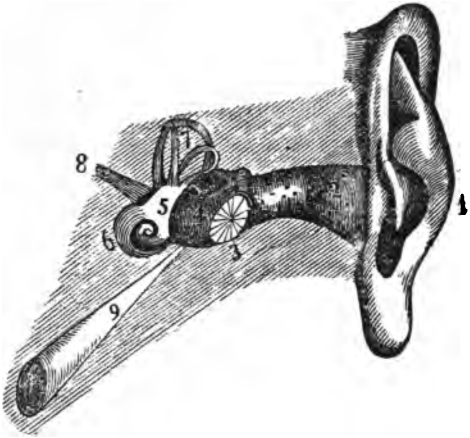
137. How is the eye liable to injury? How should the eye under such circumstances be treated? How does the general health affect the eye? How should the eye then be treated?

Section II.—The Sense of Hearing.

138. The organ of hearing consists of the external ear, the ear tube, the tympanum, and the labyrinth. **The external ear** (1, Fig. 80) is a cartilaginous substance, situated around the orifice of the ear tube. It is probably useful to some extent in collecting the vibrations of the air and directing them toward the internal ear. Yet, in cases where the external ear has been destroyed or wanting, the delicacy of hearing seems not to be sensibly diminished. In the lower animals the form of the ear is more distinctly funnel-shaped, and is movable at pleasure,

Fig. 80.



The Ear. 1 The external ear. 2 The ear tube. 3 The membrana tympani. 4 The tympanum. 5 The vestibule. 6 The cochlea. 7 The semicircular canals. 8 The auditory nerve. 9 The Eustachian tube.

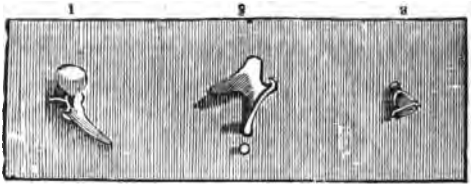
Section II.—**138.** Of what does the organ of hearing consist? Describe the external ear. How do the lower animals differ from man in the form and use of the external ear?

so that it may be directed toward the object from which sounds come. There are muscles suitably situated for giving these motions to the human ear, but, either from neglect or otherwise, these muscles are not under the control of the will.

139. **The ear tube** (2) is a cylindrical cavity extending about an inch inward from the external ear. It is lined with a membrane continuous with the external skin, and in this membrane are situated numerous follicles from which the ear-wax is secreted.

140. **The tympanum** (4) is a continuation of the ear tube for about a third of an inch, and is separated from it by a thin membranous partition (3), the *membrana tympani.* The cavity of the tympanum has, therefore, no communication with the external air through the ear tube, but there is a long, funnel-shaped tube (9) proceeding from the upper and back part of the throat and opening into the tympanum. This is the **Eustachian tube,** and serves to keep the air of the same tension on both sides of the membrana tympani. The tympanum communicates with the labyrinth by two small openings in the bone, of which the upper one is called the *fenestra ovalis,* and the

Fig. 81.



The Bones of the Ear. 1 The malleus. 2 The incus. Just below the incus is the small orbicular bone. 3 The stapes.

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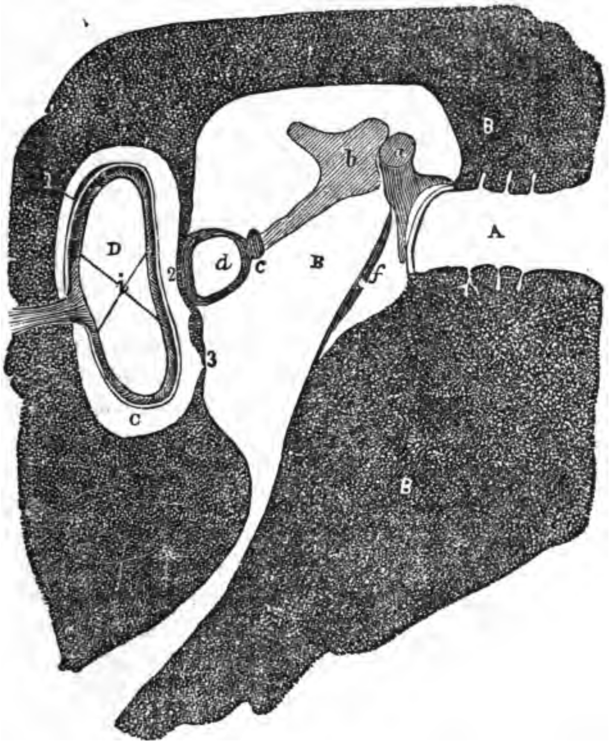
139. Describe the ear tube.

140. The tympanum. The Eustachian tube. How is the tympanum separated from the ear tube? How are the tympanum and labyrinth connected? How does the membrana tympani connect with the fenestra ovalis?

lower one is the *fenestra rotunda.* These windows are closed by an extension over them of the common lining membrane of the ear. Within the tympanum are four small bones (seen separately in Fig. 81), the relative positions of which are seen in Fig. 82. The first (the *malleus*)

Fig. 82.



An ideal representation of the principal parts of the Ear. A The ear tube, separated by a membrane from B, the tympanum. *a b c d* The small bones of the tympanum. *a* Rests against the membrana tympani, and its position may be slightly changed by the muscle *f*. *d* Rests against the membrane 2 of the fenestra ovalis. 3 Is the fenestra rotunda. C May be taken to represent generally the labyrinth, and D, the membranous labyrinth, both filled with the liquor of Cotunnius.

is placed against the inner surface of the membrana tympani, and the other two (the *incus* and *os orbiculare*) continue the connection to the last (the *stapes*), which is placed against the membrane of the fenestra ovalis. They are so arranged as to form a compound lever, and so connected with muscles (of which muscle *f*, Fig. 82, is the most important) that the two extremities of the lever are exactly fitted at all times to their respective membranes.

141. The labyrinth consists of the vestibule, the cochlea, and the semicircular canals. **The vestibule** (5, Fig. 80) is a cavity about equal in size to a grain of wheat, and situated immediately beyond the fenestra ovalis. The anterior part of the labyrinth is **the cochlea** (6). It is of a pyramidal form, and resembles a snail shell. Its spiral hollow makes two and a half revolutions, and is separated throughout its whole extent, except at its apex, by a lamina of bone. One division of the spiral terminates at the fenestra rotunda, and the other opens into the vestibule. The posterior part of the labyrinth consists of the **semicircular canals** (7), which are three bent tubes, the planes of which are situated at right angles to each other, and which open into the vestibule. These parts, lined with a delicate membrane, constitute the **osseous labyrinth.** Besides this, there is a **membranous labyrinth**, of the same form as the osseous (with the exception of the cochlea), and lying within it. The parts of the labyrinth highly magnified, are seen in Fig. 83. The general relations of the several parts of the ear (but not the form) will be gathered most readily from Fig. 82.

142. The auditory nerve (8, Fig. 80), which is a por-

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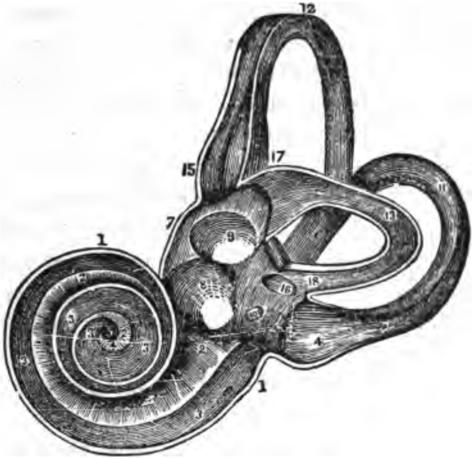
141. Of what does the labyrinth consist? Describe the vestibule. The cochlea. The semicircular canals. The membranous labyrinth.

142. Give the distribution of the auditory nerve. What is the object of the lining membrane of the labyrinth?

Fig. 83.



The labyrinth distinct from the bone in which it is situated, and highly magnified. 1 The cochlea. 3, 3 The spiral tubes of the cochlea. 2, 2 The lamina of bone by which they are separated. 7 The vestibule. 8 The fenestra rotunda. 9 The fenestra ovalis. 11, 12, 13 The semicircular canals.

tion of the seventh cranial pair, is distributed over the interior of the membranous labyrinth, and over both surfaces of the lamina by which the cochlea is divided. The cavities of both labyrinths are filled with a limpid, transparent liquid, secreted from the surface of the lining membrane, and called the *liquor of Cotunnius.* Thus both sides of the substance over which the nerve is spread are bathed in this liquid.

143. The vibrations of the air enter the ear tube, and reach the membrana tympani. The motions which it receives are transmitted, by the system of bones within the tympanum, to the membrane of the fenestra ovalis. The

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143. Describe the course of the vibrations of the air till they reach the nerve. If the membrana tympani were destroyed, how would the vibrations reach the nerve? How is the sensation of hearing produced?

same motions are also transmitted by the air within the tympanum to the membrane of the fenestra rotunda. Thus the two membranes which connect with the labyrinth are acted upon by the vibrations of the air, and communicate those vibrations to the liquid of the labyrinth; in which the nerves of hearing terminate.

Thus far we can trace the physical causes upon which hearing depends. We know that these nerves must be compressed by each vibration, that they extend to the brain, and that the immediate consequence is hearing. But why this compression of the nerve should be followed by sensation, and this sensation be hearing, is entirely unknown.

144. These vibrations of the air are produced by the vibrations of some solid substance. Thus, if the string of a musical instrument be drawn aside from a right line, and left to its own tension, it will not only return to a right line, but the velocity acquired will carry it nearly as far to the opposite side as it had at first been drawn from its natural position. This oscillation will continue for some time, and will communicate a vibratory motion to the air. The same vibrations may be communicated in various ways, as by a bell, the prongs of a tuning-fork, the springs of an accordeon, or the vocal cords of the larynx, etc. It is these atmospheric vibrations[49] which are transmitted to

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[49] Whatever will facilitate the transmission of these vibrations, will assist the hearing. Thus, a speaking-trumpet enables the speaker to give greater force to the vibrations in a particular direction. In a large room where many persons are talking, or when machinery is in operation, the voice is scarcely audible, the vibrations are so much interfered with. But by speaking through a continuous tube the voice may be sent to various parts of a building, and be heard distinctly.

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144. How are the vibrations of the air produced? How is it proved that the air is the medium of transmission?

the auditory nerve, and convey the sensation of sound; for if the vibrations of any sonorous body, as of a bell, be produced in a bell-glass, from which the air has been exhausted, no sound will be perceived.

145. It is, however, not essential that the medium of communicating them should be the air. Solid substances are good conductors. The tick of a watch held in the mouth will be scarcely heard till it is allowed to touch the teeth, when the sound will become distinct. The earth, ice, and even water, are good conductors of sound.[60]

146. Many attempts have been made to ascertain what special purpose is accomplished by each part of the labyrinth. There seems to be some reason for regarding the cochlea as the mechanism by which we recognize musical sounds. The functions of the other parts have not been definitely ascertained.[61]

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[60] It is said that the discharges of cannon at the battle of Bunker's Hill were heard at the distance of a hundred miles by placing the ear to the ground. The Indians of the prairies are in the habit of applying their ear to the ground to ascertain whether droves of wild horses are approaching. The conducting power of solids can be well shown by applying the ear to one end of a long stick of timber, and letting the other end be slightly scratched with a pin; a very feeble sound will be transmitted a hundred feet, and seem to be scarcely diminished. A person will be convinced of the conduction of sound by water if he will put his head under water, and strike two stones together; the sound is much greater than in the open air.

[61] The intensity of sound it is thought that we judge of by the tympanum, the musical note by the cochlea, and the quality of sound by the semicircular canals—meaning by quality that peculiarity by which we distinguish persons by their voices or two musical instruments from each other, though the loudness and the musical note be the same.

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145. What other substances besides the atmosphere will act as conductors of vibrations?

146. What are the functions of the several parts of the labyrinth?

147. In order that this sense be perfect, the whole apparatus in a perfect state is required; and yet the external ear may be lost and hearing still remain; the membrana tympani may be broken, and the vibrations may still reach the nerve through the air which is in contact with the membrane of the fenestra rotunda; and even when all these means are taken away the nerve may be, to some extent, affected by vibrations communicated to it through the bones of the head. But when the nerve itself is injured, hearing is impossible. Hearing is quite destroyed also by the absence of the liquid in the labyrinth.

148. There are, however, several ways by which hearing may be more or less interfered with. The membranes may become rigid or thickened, and can be restored only by a generally improved condition of the system. The secretion in the ear tube may be excessive and fill the tube, or it may harden on the membrana tympani. This can generally be relieved by softening the secretion with a few drops of sweet-oil in the ear, and after an hour or two syringing the ear with soap and warm water. If this treatment does not in a short time give relief, it is because the deafness depends upon other causes, and no external application can avail. Deafness may arise from a closure of the Eustachian tube; as the lining of this tube is the same membrane that lines the nasal cavities, a cold, that is, an inflammation of this membrane, is very likely to increase its thickness so as to fill the tube. In such cases the deafness will generally subside with the inflammation. When the tube becomes closed by the permanent enlargement of the tonsils, it is necessary for the deafness as well as for the general health that they should be removed.

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147. How much of this apparatus is essential to hearing? What parts may be lost without destroying the sense?

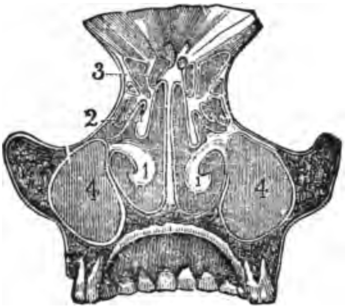
148. What are among the ordinary causes of deafness? How is each to be treated?

The ear becomes exceedingly painful in consequence of such a degree of inflammation in the ear tube as to bring on ulceration. The inflammation should always be checked, if possible, in an earlier stage by cold applications, or, if necessary, by local bleeding, such as cupping or leeches.

Section III.—The Sense of Smelling.

149. This sense has its seat in the surface of the outer part of the air passages to the lungs; and it seems to depend for its acuteness upon the amount of surface over which the nerve is spread. In order to increase this surface, in the first place, there are three thin sheets of bone (the turbinated bones) which lie partly rolled up within each nasal cavity (1, 2, 3, Fig. 84). In the second place, there are several cavities in the bones of the head and face, not otherwise employed, which are made to commu-

Fig. 84.



A vertical section of the bones of the face a little forward of the ears. 1, 1 Lower spongy bones. 2, 2 The middle spongy bones. 3, 3 Superior spongy bones. 4 Antrum maxillare.

Section III.—**149.** Upon what does the acuteness of this sense depend? How are nasal surfaces increased?

nicate with the nasal passages and form part of the nasal surfaces. Two of these are the antra maxillaria and the frontal sinuses.

150. Over all these surfaces is spread **the Schneiderian membrane**, the object of which is to deposit a mucous secretion, by which, in a healthy state, they are continually moistened.

151. The olfactory nerve enters the nasal cavities through the sieve-like apertures in the ethmoid bone, and branches are distributed by division and subdivision over every part of this membrane.

152. It has been doubted whether odors consist of material particles emanating from odoriferous bodies; whether, for instance, material particles escape from the rose to diffuse its odor; for, in the first place, the continual escape of odors does not seem to diminish its substance, and, in the second place, analyses do not detect the chemical particles of which its odors consist. In many other cases, however, they are known to be material, and it is presumed they always are. But, whatever be their nature, these odors, diffused through the atmosphere, are drawn into the nose, and coming in contact with filaments of the olfactory nerve, the impression of them is conveyed by the nerve to the brain, and the sensation of smelling is the result.

153. It has been noticed that the nasal surfaces constitute the sides of the usual air passages to the lungs, so that the same muscular effort which is expended in respiration causes a current of external air, with whatever

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150. How are these surfaces covered?

151. What is the distribution of the olfactory nerve?

152. Describe the process by which smelling is produced.

153. What are the advantages of making the air passages and the nasal cavities the same? How is the air made to come in close contact with the nasal surfaces? How do we voluntarily increase the effect of odors?

odors it may contain, to pass over these surfaces and come in contact with these nerves. It is also to be observed that the turbinated bones, while they increase the surface over which the olfactory nerves are spread, partially fill up the spaces, so as to require the air in passing to come more in contact with the surfaces thus increased. And whenever we wish to stimulate this sense to the utmost, we voluntarily compress as much as possible the air passages, and cause the current of air to strike upon them with considerable force.

154. This sense may be useful, to some extent, in assisting us to discriminate between useful and hurtful food. Possibly it is useful in removing from the air some elements which, if taken into the lungs, might be hurtful. It is unquestionably serviceable as a warning against noxious vapors. And yet it seems to be the sense least essential to our existence, and having, more than any other sense, for its special object simply to increase the enjoyments of life.

155. The Schneiderian membrane is so situated as to be, perhaps, the most exposed of any part of the system to variations of temperature; and these changes often produce the inflammation and secretion which we speak of as a cold in the head. But this membrane is also always liable to indirect disease, by taking on the extra labor of the system when the excretions have been checked in other parts. Hence, a cold is likely to show itself in the nasal cavities first, and the excessive secretion indicates not so much a disease of that membrane as of suppressed action elsewhere, generally of the external surface.

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154. How is this sense useful?

155. What is a direct cause of disease in this membrane? What is indirectly the cause of diseased action?

Section IV.—The Sense of Tasting.

156. This sense has its seat in the tongue, and, to some extent, in all parts of the mouth. The tongue is covered with fine filaments called *papillæ*, which give it a velvety appearance. On the edges of the tongue there are also other papillæ, of larger size, conical form, and brighter color. These papillæ, of both kinds, but particularly the larger ones, contain the terminations of the lingual branch of the fifth pair of cranial nerves.

157. Substances which are capable of solution and of being tasted are called sapid substances. When the saliva containing such substances in solution flows around these papillæ, the impression which they make upon the nerve within is communicated to the brain, and the sensation of tasting is produced.

158. When substances which produce an agreeable taste are placed in the mouth, there is an increased secretion of the saliva[52] to facilitate the solution of it and promote the gratification of this sense. The taste is also rendered more acute by pressing the tongue against the roof of the mouth, and thus bringing the particles which produce the

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[52] To promote this increased action of the salivary glands, it is not necessary that the substance should be placed in the mouth. The sight, or sometimes the thought, of any substance particularly gratifying to the taste, will have this effect, make the mouth water. The effect is a physical one, but the cause is a sympathy between the state of the mind and the action of the gland, of which we can only record the fact without giving any explanation.

***Section IV.*—156.** Where is the sense of tasting situated? Describe the surface of the tongue, and the distribution of the nerve of taste.

157. How is the sensation produced?

158. In what two ways is this sense rendered more acute?

impression in closer contact with the nerves upon which the impression is produced.

159. Attempts have been made to classify the varieties of taste, though with but little success. They are, however, more distinct than the varieties in the sense of smell; for they have, to some extent, received distinct names, such as sweet, acid, bitter, metallic, etc.

160. The taste is a sense of importance to us in enabling us to discriminate between wholesome and hurtful food. It is a general rule that those substances which are agreeable to the taste the stomach will easily digest, and those which are not agreeable, if swallowed, the stomach will not act upon and is disposed to reject. A person with a disordered state of the system, or when recovering from a long illness, may desire the most hurtful kinds of food; the taste may also be perverted by the use of tobacco, alcoholic drinks, or food seasoned to excess; but these are exceptions which do not invalidate the rule nor diminish its practical value.

161. The taste, though capable of being abused in this capacity quite as much as any other faculty, is yet one of the prominent sources of innocent physical enjoyment; and it is intended to be so, not simply for the enjoyment which it affords, but also as the natural motive to us to take food. The act of eating is not made compulsory upon us and removed from the control of the will lest we should forget it, as that of breathing is, but it is specially stimulated by the gratification of the sense of taste, which is necessarily connected with it. As we naturally seek to

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159. How are the varieties of taste indicated?

160. What is the principal use of the sense of taste? What is the general rule by which the taste should govern us in the selection of food? What are exceptions to this rule?

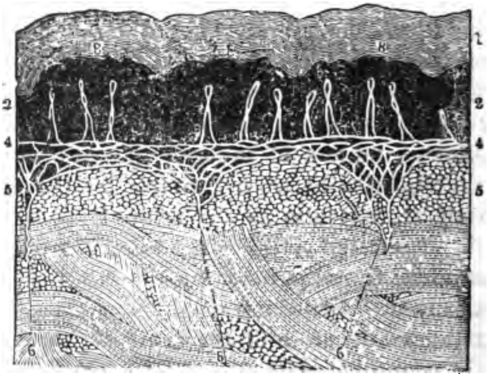
161. How is this sense made subservient to the continuance of life? How to the preservation of health prolong this gratification, it encourages us to take our food not too rapidly, to masticate it sufficiently, and to mingle it thoroughly with the saliva, all of which are essential to continuance of health.

Section V.—The Sense of Feeling.

162. This sense has its seat in the skin and exists on the whole surface of the body, but is more acute in the hands and at the ends of the fingers.

163. The skin is composed of two principal layers. The outermost is the *cuticle* (1, 1, Fig. 85). It is this

Fig. 85.



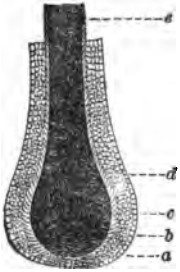
1, 1 The cuticle. 2, 2 The colored layer. 4, 4 The network of nerves on the surface of 5, 5. the true skin. Filaments of nerves go from this network into the papillæ, 8, 8, 8. 6, 6, 6 Nerves which divide to form the network.

***Section V.*—162.** Where is this sense situated?

163. Of how many layers is the skin composed? Describe the cuticle. The layer in which the coloring matter is found. Upon what does its quantity depend?

layer which is raised by scalds or blisters. It is destitute of nerves or blood-vessels, and is regarded as merely a secretion from the true skin and hardened by exposure. At the under surface of the cuticle is a thin layer (2, 2), consisting, not of a network, as was formerly supposed, and from which supposition it was called the rete mucosum, but of unorganized gelatinous matter. It is secreted, as the cuticle is, from the true skin, but has not become hardened. It is, in fact, cuticle in a state of formation. It contains the coloring matter which is so abundant in the African[53] and some other races, and which is never wholly wanting in the healthy European. Its color, always more or less dark, varies with the race, the temperament, and the habits of the individual.

Fig. 86.



a The base of the follicle where the cells are supplied which form both the covering and the interior portion of the hair. *b* Cells to form the exterior part of the hair. *c* The same cells taking the form and arrangement of imbricated scales. *d* The interior portion of the hair, the cells becoming elongated and giving the fibrous structure to the hair as it approaches *e*, and protrudes beyond the skin.

164. **The hair and nails** are of the same nature as the cuticle, being secretions simply, and containing no nerves or blood-vessels, and possessing no vitality. The hair is formed in a sac or follicle (Fig. 86) situated in the substance of the true skin, and passing through the cuticle by a narrow opening. In the bottom of this sac cells are continually forming; one portion of which, as they advance, become an imbricated covering of the hair. The other portion of the cells go to form the central portion, and among these are found colored oily particles which give color to the hair. The growth of the hair depends on the accumulation of new cells at the base, which thrust forward the shaft of hair already formed.

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[53] In the Albino there are the features and all the peculiarities of the African, except a total absence of color.

164. Describe the growth of the hair.

165. The nails are developed in a very similar way. Each nail may be regarded as a hair increased in size and flattened, or as a succession of hairs placed side by side, and the several sacs in which they are formed coalescing into one of sufficient width to receive the root of the nail.

166. The true skin (5, 5, Fig. 85) is a dense, elastic membrane, situated in contact with the muscular parts of the body, and defends them from injury. It is covered with a plexus of nerves (4, 4), and the terminations seem to be coiled up so as to form little mounds (8, 8), which are called papillæ. On the ends of the fingers they are most abundant, and disposed in rows. They contain the nervous filaments from the posterior roots of the spinal nerves.

167. Almost all of the physical properties and states of bodies, such as form, hardness, locomotion, vibration, temperature, etc., are capable of acting upon the nerves of this sense. The nerves convey these several impressions to the brain, where the sensation is produced.

168. This sense, when specially trained (as it often is by those whose business it is to judge of the fineness of fabrics), becomes very acute. In blind persons it almost answers the purpose of sight. By this sense they read rapidly with raised letters, and sometimes without the letters being raised. But it is of the highest importance to us without this special training. It is most favorably situated, at the extremities of the fingers, for extensive use. Scarcely any common employment, such as the use

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165. How are the nails developed ?

166. Describe the true skin.

167. How is the sense of feeling produced ?

168. Under what circumstances does this sense become specially trained ? What is its use in an ordinary state ?

of the needle or pen, could be carried on without it; but it is more indispensable in those processes which require special skill.

169. It communicates certain kinds of knowledge which we could not receive in any other way. We could not, for instance, have the idea of temperature, of the existence of heat and cold, without this sense. It is also less likely to be deceived than most of the other senses, and hence it is employed to verify the evidences of the other senses.[64] It is also made to co-operate with other senses: thus, we judge of distance by sight ordinarily, but not till we have learned by the sense of feeling at what distance certain differences take place in the appearance. We judge of form by the sight, but we also determine form by the sense of feeling, and then connect the ideas of the various forms with the impressions which they produce on the organs of sight.

170. The systems of organs which we have hitherto considered are subject to periodical suspension of their functions, constituting *sleep*. After giving attention to some of the processes of the repairing system, we shall be better prepared to understand the necessity for this suspension of activity. But the necessity exists, even if we can assign no reason for it. It is so far subject to the will that, if we choose, we can generally defer it several hours, but beyond a certain period it is impossible to resist the demand for it. The eyes close involuntarily; the voluntary muscles

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[64] And Thomas said: "Except I shall see in his hands the print of the nails, *and put my finger into the print of the nails, and thrust my hand into his side, I will not believe.* Then Jesus saith to him: *Reach hither thy hand, and thrust it into my side, and be not faithless but believing.*"

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169. How is it essential in the acquisition of certain kinds of knowledge? With what sense does it chiefly co-operate in making us acquainted with the external world?

170. What is sleep? To what extent is it subject to our control?

refuse obedience to the will; the external senses cease to act; all intellectual operations are suspended, and sleep inevitably supervenes.

171. The amount of sleep needed varies with the temperament somewhat, with the age, the health, and the degree of indulgence which a person will allow himself; but the amount absolutely required by an individual who has acquired his full strength depends simply upon the amount of activity, physical and mental, which is put forth. From five to eight hours may profitably be given to sleep. Eight hours is probably better than less. It is mistaken economy to attempt to reduce the amount of sleep below what the system craves.

172. It is, however, possible so to train the powers that some of them may be either not at all suspended, or but very partially so. Thus, a person may accustom himself to sleep while riding on horseback, but there must be the continued exercise of sufficient muscular effort to keep the erect position. A physician will accustom himself to sound sleep in every other respect, while the sense of hearing is so far awake that his own name, though spoken in a low voice, will always arouse him.

173. With most persons, however, sleep is for several hours complete; that is, all of the faculties which are subject to it are completely suspended. But the continuance of this suspension is not the same for all of the faculties. Some, which have become sufficiently rested, begin to act before the others are aroused. Some persons plan their business for the day while the muscular powers and the senses are still asleep; the mind being first sufficiently rested for renewed activity. Under the same circum-

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171. How much sleep is necessary?

172. Do the faculties all sleep?

173. Do they all require the same amount of sleep? Give examples of the activity of certain powers while the others are asleep.

stances there is no doubt but that difficult problems in the arts and mathematics have been solved. It may be called dreaming, but it is simply an energetic action of the intellectual powers, rendered more perfect, because none of the powers of the system are otherwise employed, and because the succession of thoughts is not interfered with by impressions coming from without. When the powers of voluntary motion are awake and the others are asleep, the person may take the most active exercise, or walk, sometimes for miles, without arousing the other powers.

174. Incubus, or nightmare, admits of a similar explanation. When the mind first awakes, the train of associations may, from various causes, be of a disagreeable character. Particular ideas may have been so constantly in the mind before sleep came on that they most readily return. The imminent danger from which we had escaped the previous day may have impressed us so vividly, that the thoughts of it first occur to the mind when its powers are aroused. A sudden noise, an uncomfortable position, cold feet, or disturbed digestion, may predispose the mind to alarming conceptions. Every conception is, by our constitution, attended with a belief of the existence of the object to which the conception corresponds. In case of incubus, the object of conception does not exist, and yet, as the senses, which are the corrective agents, are asleep, there is necessarily a belief that it does exist. There is no avenue open by which a person's mind can be reached to convince him that his conception is erroneous. He therefore suffers all that would result from real danger; at the same time the power of muscular action is asleep, and he can make no efforts to relieve his condition.

175. Dreaming seems to consist in a certain degree of

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174. How is incubus explained?
175. Dreaming?

activity of the mind, while some of the other powers are also active to such an extent that they are continually interrupting the succession of thoughts, and yet do not control them. Hence arises the want of continuity in our dreams and the succession of such incongruous ideas. Hence, also, the observation, so often made, that such sleep does us but little good; it does not rest us, and simply because it is not sleep.

GENERAL QUESTIONS ON THE NERVOUS SYSTEM.

What are the parts contained in the nervous system?

CHAPTER I. SECTION I.—What is the subject of this section? Describe the membranes of the brain and the duplications. What are the divisions of the brain? Describe the surface of the cerebrum and the connection of the hemispheres. Of what substances is the brain composed, and how are they arranged in the several divisions? What are the functions of the brain? How are they to be learned? Why not from an examination of the organization of the brain? What is the first law in reference to the use of the brain? What are the results of a proper exercise of the brain? Can the brain be overworked? What are the practical rules in this respect? Upon what does the healthy action of the brain depend? How should a naturally excessive activity be managed? How do the emotions affect the intellectual operations?

SECTION II.—Describe the spinal cord. What are the functions of the white substance of the brain? Of the gray substance?

SECTION III.—What are the nerves? Describe the cranial nerves. Describe the spinal nerves. Describe the origin of the spinal nerves. Their distribution. How is a general nervous sympathy established? Describe the great sympathetic. What are the functions of the nerves? Describe those of special sensibility. What are the nerves of general sensibility? What sensations are dependent upon these nerves? How do they protect the body? Is their sensitiveness ever injurious? Give examples of the adaptation of these nerves to particular purposes. What are the nerves of voluntary motion? What is the relation between the nerves of motion and those of sensation? What are the nerves of involuntary motion, and what are the particular functions of each?

CHAPTER II. SECTION I.—Describe the external parts of the eye. The internal parts. The action of the refracting substance upon the rays of light. How is vision produced? What is the direction in which a visible object is seen? Why are objects seen erect? Why is but one object seen? How is spherical aberration prevented? How does the eye adapt itself to different degrees of light? To different distances? How are long and short-sightedness corrected? How

does the eye adapt itself to different distances? What practical rules must be observed in the use of the eye?

SECTION II.—Describe the ear. The ear tube. The tympanum. The labyrinth. How is hearing produced? By what substances must the vibrations be conveyed? Upon what does the perfection of the ear depend? What parts are absolutely essential? To what diseases is it subject, and how are they to be treated?

SECTION III.—Describe the organ of smelling. How is the sensation produced? What evidences of design are observed in the position and structure of the nose? What are the functions of the nose? To what diseases is it subject?

SECTION IV.—Describe the organs of taste. How is the sensation produced? What are the uses of this sense?

SECTION V.—Describe the organs of feeling. How is the sensation produced? What are the purposes to which the sense of feeling is subservient?

What peculiarity have the mechanical and nervous systems to distinguish them from the repairing system? How much sleep is required? How are the different powers affected by sleep? Explain the phenomena of sleep-walking, dreaming, incubus, etc.

PART III.

THE REPAIRING SYSTEM.

176. The body is subject to constant waste. The vital motions, the mechanical forces of the body, the development of heat, and even the processes of thought, are necessarily connected with wear, and therefore waste. While the body is growing the supply must be greater than the waste; but when the body has attained its growth, the supply is exactly equal to the waste. Our food, that is, all that is taken into the system, whether in the solid, liquid, or gaseous form, constitutes this supply.

177. Our food, regarded in its more limited sense, consists of certain chemical combinations which depend for their existence wholly on the processes of vegetable life. We cannot produce them by the chemical processes of the laboratory. It is only by that secret working of the Divine power which we call vegetable growth, that they can be produced. The only invariable constituents are oxygen, hydrogen, and carbon. To these are frequently added nitrogen, and sometimes phosphorus, sulphur, and lime. The chemist can effect various combinations of these substances, but none which constitute food. Vegetable life

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176. From what arises the waste of the system? What is the object of food? How much is necessary?

177. Why is vegetable life necessary to animal life? What are the invariable constituents of food? What others are frequently contained in it? What division is made of the materials for our nutriment?

is, then, a condition of animal life, and therefore of human life.

But our food, though only the product of vegetable growth, has often been still further elaborated by animal life, so that it properly receives the name of animal food. One of the most common divisions of the materials for our nutriment is, therefore, into *animal* and *vegetable* food.

178. We have seen that food may consist of oxygen, hydrogen, and carbon, without nitrogen. These three, in due proportion, constitute the sugars, the fats and oils, and all of the farinaceous varieties of food. They have been supposed to support the respiration of the system to great extent, but never to enter into the formation of the tissues of the body. They have, therefore, been called ***respiratory elements***, or ***non-nitrogenized elements.***

179. But much of our food contains nitrogen in combination with the other three elements, and is employed in the formation of the flesh, the membranes, and other tissues of the body. It constitutes, therefore, the ***nutritive*** or ***nitrogenized*** portion of the food. The elements of nutrition may take the form of fibre, as in the lean meat of animals; of gluten, as in the adhesive portion of wheat flour; of casiene, of which cheese principally consists; or of albumen, as in the white of the egg. This distribution of food into elements of respiration and elements of nutrition is important, in order to understand the vital changes in the system.

180. The processes of receiving food, of whatever form, into the system, of elaborating it, and then of eliminating it, comprise all of the functions of the repairing system.

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178. What are the constituents of the respiratory elements? What varieties of food belong to this class?

179. What are the constituents of nutritive food? What four forms may this kind of food take?

180. Give an analysis of the repairing system.

But a full examination presents to us, 1st, a *digestive* system, by which food is taken into the body and by which the nutritive part is separated from the useless and introduced into the blood; 2d, a *circulating* system, an arrangement of tubes and forcing apparatus by which the nourishing fluid, the blood, is carried through the body and appropriated to the building up of the several parts; 3d, a *respiratory* system, an arrangement by which the oxygen of the air is incorporated with the blood, carried to all parts of the body, and is thus enabled to decompose (burn) the structures which the food has built up; 4th, an *absorbent* system, a kind of scavenger arrangement by which such material as has for any purpose been removed from its regular channels may be picked up and again made use of; and 5th, a *secreting* system, by which all material, as it becomes refuse, may be removed from the body. There are, therefore, five classes of organs belonging to the repairing system.[55]

CHAPTER I.—OF DIGESTION.

181. The food is not in a condition to be used in the repairs of the body without undergoing many changes, all designed to render the food soluble, so that in the liquid state it may be absorbed into the system and mingled with

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[55] In this analysis of the repairing system it is the object to name only such functions as constitute one complete circle, and thus associate the several classes of these organs naturally together. It is not intended to be a full enumeration of these functions: the secretions for lubrication, the absorption of chyle, the development of animal heat, and many others equally important, belong to this system.

Chapter I.—181. What form must food take before it can be absorbed into the system? What processes are necessary in completing the work of digestion?

the blood. Part of this process is mechanical, and is performed by mastication. Part of it is chemical, and is performed in the stomach and intestines. Part of it consists in separating the nutritious from the useless portions. Such is the general object of the digestive system.

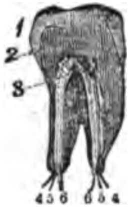
182. The abdomen, which is the cavity containing the principal digestive organs, lies between the thorax and pelvis, and is lined by a serous membrane called the *peritoneum*. It secretes a fluid by which the interior of the abdomen is moistened and lubricated. It has another important office, that of forming the outside coat of the stomach and most of the other viscera of the abdomen.

Section I.—The Organs of Mastication and Deglutition.

183. These organs are the teeth, salivary glands, the tongue, the pharynx, and the esophagus.

184. **The teeth** are composed of ivory and enamel. The ivory (2, Fig. 87) is harder than ordinary bone, and constitutes the principal part of the tooth. The enamel (1) is the densest material in the body. It is a thin layer on the outside of that part of the tooth not imbedded in the alveolar process. The purposes to which the teeth are subservient require that they should be composed of materials too compact to allow nerves and blood-vessels to penetrate them; hence the teeth, unlike the

Fig. 87.



Section of a Molar Tooth. 1 The enamel. 2 The body of the tooth, composed of ivory. 3 The cavity in the centre of the tooth, in which is seen the terminations of a nerve, 4, a vein, 5, and an artery, 6.

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182. Where are the organs of digestion situated? What is the name and office of the lining membrane of the abdomen?

Section I.—**183**. What are the organs of mastication and deglutition?

184. Describe the teeth.

other osseous parts, when injured cannot be repaired by any natural process. Hence, also, they are developed in a different way from that of any other organs.

185. The first indication of the formation of a tooth is the existence of a small transparent vesicle in the interior of the alveolar process. That portion of the vesicle corresponding with the body of the tooth gradually enlarges till it acquires the size the tooth is to have, and is filled with a transparent liquid. The outer surface of this vesicle soon deposits a shell of ivory, of the same shape and nearly of the same size which the crown of the tooth is to have after it emerges from the gums. After the shell is formed, the vesicle remaining within it continues to deposit ivory, and thus becomes itself reduced in size as the walls of the tooth become thicker, until only a small hollow (3) is left, which the perfect tooth always contains. This hollow is still lined by the vesicle, and receives an artery, a vein, and a branch from the fifth pair of cranial nerves.

The tooth is covered with another membrane, which deposits from its inner surface a layer of enamel (1) on the body of the tooth.

The body of the tooth being now completed, the central vesicle begins to be produced into one or more smaller prolongations, according to the number of roots which the tooth is to have. While the roots are forming, the body of the tooth is thrust forward and cuts through the gums.

The first set of teeth contains but twenty, the double molars being wanting. As the alveolar processes of the child enlarge, these teeth become loose, the roots are absorbed, and they are easily extracted.

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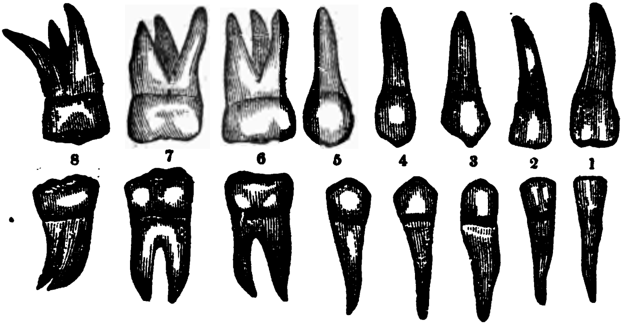
185. How is the ivory produced? The enamel? The root? Describe the first set of teeth.

186. The second set consists of thirty-two, eight in each jaw on each side. The first and second in front (1, 2, Fig. 88) are thin, have sharp, cutting edges, and are called *incisor* teeth. The third (3) is a strong tooth deeply set, is brought to a blunt point, and is called the *canine* tooth. The fourth and fifth (4, 5) have each one root, somewhat flattened surfaces, and are called *single molar* teeth. The sixth, seventh, and eighth (6, 7, 8) have three roots in the upper jaw and two in the lower, large bodies, broad surfaces, and are the *double molar* teeth. Thus there are eight incisors, four canine teeth, eight single molars, and twelve double molars.

Fig. 88.



The Second Set of Teeth in both jaws. 1, 2 The incisor teeth. 3 The canine teeth. 4, 5 The single molar teeth. 6, 7, 8 The double molar teeth.

187. The teeth are designed to last a lifetime, and should, therefore, be carefully attended to. In the first place, care should be taken *to prevent deformity.* If the first teeth are not removed at the proper time, this does not prevent the teeth of the second set from coming, but

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186. The second set.

187. What causes tend to produce irregularity in the arrangement of the teeth? How may the irregularity in both cases be prevented?

it compels them to make their appearance where they ought not to be, either back of the other teeth, so as to be in the way of the tongue, or in front of the other teeth, so that the lips will scarcely cover them. If, however, the tooth of the first set is removed[56] as soon as the second is perceived, the second will generally come into its proper place.

It sometimes happens that the teeth are too wide for the space which they are to fill, and some of them must either be too prominent or they must be set irregularly. In such cases, the only way is to have a tooth removed, so that those which are left may have sufficient room.

188. In the second place, no *foreign substance* should be allowed to remain on or between the teeth. They should be washed with a brush and water after every meal; otherwise particles of food which remain between the teeth will, by decomposition, render the breath offensive, and ultimately cause the decay of the enamel.

A solid substance called *tartar* also frequently collects on the teeth, and extends toward the roots so as to loosen the gums and make them tender. When this has accumulated in considerable quantity, the aid of a dentist may be necessary to remove it; but its accumulation may always be prevented by proper attention to washing the teeth.

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[56] The removal of teeth is, however, unnecessarily performed in many instances. It is the shortest way to overcome deformity, or to prevent toothache, or to remedy offensive breath; but the peculiar character of the teeth should make us unwilling to resort to extraction except in extreme cases. Perhaps no fault is more common among dentists than to advise extraction for insufficient cause. The perfection of his art is to preserve the natural teeth—his last resort is to supply their place by artificial ones.

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188. Why should the teeth be cleansed after eating? What is the effect of tartar upon the teeth?

189. In the third place, great care should be taken to preserve the enamel. It is specially designed by its hardness to protect the ivory of the tooth; but this property also increases its brittleness, and renders extremes of temperature, from taking very hot drinks or very cold, such as ice-water or ice, or any excessive pressure upon them, such as cracking nuts or cutting threads, likely to injure them permanently. When the enamel of a tooth is cracked, so that the air or the liquids of the mouth can get to the ivory, the tooth soon begins to decay, and is often reduced to a mere shell of enamel before we are aware of any imperfection.

But when the teeth do become defective, the decay can, if taken in season, be arrested by having the decayed portion removed and the cavity filled with gold. This is important, in order to preserve the features, the voice, the health, and the means of masticating food. Its importance is indicated by the severe pain which, as a warning, is liable to attend such decay. When, however, a tooth is so far gone that it cannot be preserved, it should be extracted at once.

190. The saliva, by which the food as well as the interior of the mouth is moistened, is furnished by three pairs of *glands*. The parotid gland (1, Fig. 89) is situated below and in front of the ear.[67] The sub-maxillary gland (3) is on the inside, and near the angle of the lower maxillary bone. The sub-lingual gland (5) lies immediately under the tongue. The secretion from these glands is conveyed to the mouth by ducts (2, 4).

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[67] It is this gland which is affected by a peculiar form of inflammation, called the "mumps," to which it can be subjected but once.

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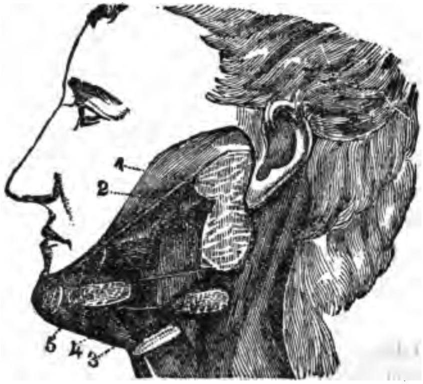
189. How may the enamel be injured? What is the result when the enamel is injured? What course should be pursued when the teeth begin to decay?

190. Describe the salivary glands.

Fig. 89.



The Salivary Glands. 1 The parotid gland. 2 The duct by which its secretion is conveyed into the mouth. 3 The sub-maxillary gland. 4 Its duct. 5 The sub-lingual gland.

The secretion from the salivary glands depends in part upon the gratification of the taste; but it is also promoted by the motions of the jaw in mastication. This is one reason why food should be eaten slowly and well masticated.

191. **The tongue** is attached at its base to the os hyoides, and the motions of this bone, by its proper muscles, carry the tongue backward or forward and raise or depress it. The tongue itself also consists of muscles, so that it can be shortened or elongated, and applied to all parts of the mouth. It is the principal organ of taste, and one of the most essential modifiers of sound; but, as connected with mastication, its office is to control the food in the mouth till it is swallowed.

192. **The pharynx** is the back part of the mouth, and is at the same time the upper portion of the tube

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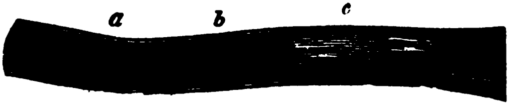
191. The tongue. What are its functions?

192. Describe the pharynx. What are the principal openings into the pharynx? Of what are the sides of the pharynx composed?

which leads from the mouth to the stomach. From the upper posterior part, the Eustachian tubes lead to the tympanums of the ears; in the upper front side are the two openings leading to the nostrils, and at the base of the tongue on the front side is the opening into the larynx and trachea. The pharynx is surrounded by muscles so arranged that by their contraction it can be reduced in length, and its sides can be brought nearly together.[58]

193. The esophagus (Fig. 90) is a continuation of the pharynx to the stomach. It is a fleshy tube composed of two sets of muscular fibres, of which the inner ones (*a*, *b*) are circular, and serve to diminish its diameter, while the outer ones are longitudinal (*c*), and by contraction tend to shorten the tube.

Fig. 90.



The Esophagus. *a b* Circular muscular fibres. *c* A layer of longitudinal muscular fibres outside of the circular.

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[58] The mucous membrane, with which this and all other parts of the alimentary canal are lined, is very liable to inflammation, producing "colds."

Just at the entrance of the pharynx there are two glandular bodies, the tonsils, which probably serve some important purpose in the system, but their use is not satisfactorily known. They are very liable to inflammation and permanent enlargement; in this state they obstruct the breathing, especially in sleep. They often almost or quite stop the breath, and they are liable to keep up an inflammation in the adjacent parts, which not unfrequently reaches the lungs. If, therefore, the enlargement cannot be reduced by medical treatment, it should be by surgical; they should be removed.

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193. Describe the esophagus.

194. The object of these organs is to prepare the food for digestion and to convey it into the stomach. The lower jaw is provided with two pairs of strong muscles, to bring the upper and lower teeth firmly together, and with two other pairs of muscles, to give them a lateral motion and cause their rough surfaces to move over each other; and by this means the food, which is kept between the teeth, on the inside by the tongue and on the outside by the lips and cheeks, is reduced sufficiently to be received into the stomach—at the same time the saliva has been secreted and mingled with the food. In this state the portion of masticated food is taken up by the tongue and placed in the pharynx. The tongue is thus so bent backward that the epiglottis, which is a cartilaginous valve attached to the root of the tongue, is laid over the opening into the larynx,[59] and the tongue itself, at the same time, closes the opening between the mouth and pharynx. By the same position of the tongue the membranous partition between the mouth and pharynx, called the *velum palati*, is raised up so as to close the orifices into the nostrils. The contraction of the pharynx itself closes the Eustachian tubes. At the instant when the food is placed in the

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[59] The epiglottis is brought into the right *direction* to cover the opening into the windpipe, but the opening is not closed till the pharynx begins to contract. By this action the larynx is raised up and the orifice brought directly under the epiglottis. It is, therefore, closed as soon as pressure begins to be exerted upon the food in the pharynx, which would tend to press any of it into the windpipe.

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194. What is the object of these organs? How is the food sufficiently reduced to be received into the stomach? What are the muscles by which the vertical motions of the jaw are produced (see Appendix)? Describe them. Describe the muscles by which the grinding motions are produced. What other preparation of the food is necessary besides mastication? What is the agency of the tongue in swallowing? How are all the openings into the pharynx, except the esophagus, closed? How is the food made to pass into the esophagus, and how into the stomach?

pharynx and these principal orifices are closed, there is a strong involuntary contraction[60] of the muscles composing the sides of the pharynx, and the masticated food is pressed into the esophagus, which, by the successive contraction of its circular fibres, forces it downward into the stomach.

195. The food thus introduced into the stomach has been finely comminuted and mingled with saliva. The saliva is a slightly alkaline fluid, and contains a peculiar substance which has the property of converting the starch of food into sugar, thus commencing the process of digestion. This sugar readily passes into lactic acid, and may thus, in some cases, co-operate with the ordinary acid in the stomach in the work of digestion there. The amount of saliva secreted, about three and a half pounds a day, would indicate that it has an important office, but the changes above stated are all that are known to occur.

Section II.—The Stomach.

196. The alimentary canal, when it has passed downward through the diaphragm, becomes at once enlarged into a bag called the *stomach* (Fig. 91) of variable

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[60] We see an obvious reason why the action of the pharynx should be involuntary and almost spasmodic. If it were otherwise there might be suspension of respiration; for, during the act of deglutition, all communication of the pharynx with the external air is cut off, and the epiglottis lies over the opening which leads to the lungs. Nature does not leave to our option any of the processes so essential to life.

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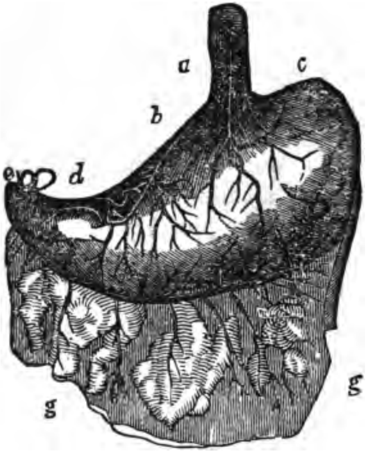
195. How much saliva is secreted per day? What action has it upon the food?

***Section II.*—196.** Describe the form and position of the stomach. The coats of the stomach.

Fig. 91.

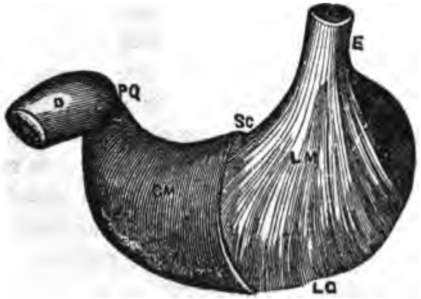


The Stomach. *a* The esophagus. *b* The smaller curvature. *c* The cardiac extremity. *d* The pyloric extremity. *f* The larger curvature. *g g* The omentum.

dimensions, but capable of containing, when moderately distended, from two to three pints. Its larger extremity is in direct contact with the diaphragm; and, as it lies obliquely across the spine from left to right, its smaller extremity is considerably lower. The opening of the esophagus into the stomach is called the *cardiac* orifice, and that at the other extremity is the *pyloric* orifice.

The stomach is composed of three coats. The exterior is of condensed cellular substance, and is in fact the peritoneum attached to its muscular layers. This outer coat, being continuous with the lining membrane of the abdomen, must retain the stomach in its place. The middle coat is muscular, and the fibres, though crossing each other in all directions, may, most of them, be classed as either longitudinal (L M, Fig. 92) or as circular (C M). The interior is a mucous layer, the inner surface of which is covered with papillæ, which gives it a velvety appearance,

Fig. 92.



Muscular coat of the Stomach.

and it is furnished with a large supply of nerves and blood-vessels.

197. When food is taken into the stomach, the circulation in the mucous coat is increased, the color changes from a pale, or slightly pink, to a bright red, and a fluid, called the *gastric juice,* which is slightly viscid, transparent, and feebly acid, is abundantly secreted.

198. At the same time the muscular fibres of the stomach are successively contracted and relaxed, and the gastric juice is thus thoroughly mingled with the food, and converts it into a homogeneous, pulpy mass, called *chyme.*

This process of changing the food to chyme is not a vital but a chemical one. If gastric juice be taken from the stomach and mingled with food in a state of minute division, and the ordinary temperature of the body be sustained, the formation of chyme will take place precisely as it does in the stomach.[61]

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[61] Many of the statements made in reference to the gastric juice and the

197. What is the effect upon the stomach of food received into it? What are the properties of the gastric juice?

198. What change in the food takes place in the stomach? How is it shown that the formation of chyme is not a vital process?

199. The food, as ordinarily taken, consists of the elements of nutrition and of respiration in varying proportions, and both of these in combination with numberless forms of woody tissue. Thus, if the potato be grated to a pulp, the water with which it is washed will deposit a white granular substance. The clear water obtained after this deposition will, when the temperature is raised nearly to the boiling point, be filled with flaky shreds. The rejected pulp is woody tissue, the granular deposit is starch, the flaky portion is albumen. The pulp is not food, the starch is respiratory food, the albumen is nutritive food.

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action of the stomach, were not regarded as fully proved, but only probable, until a circumstance occurred in Michigan, in the year 1822, which rendered it possible to subject them to the test of direct observation.

Alexis St. Martin, a healthy young man in the U. S. service, was wounded in the side by the accidental discharge of a gun. The walls of the thorax and abdomen were lacerated, so that a portion of one lung was pressed out through the wound, and an opening was also made into the stomach. The patient was put under the care of Dr. Beaumont, a surgeon in the army. The wound in the thorax healed over. The edges of the wound in the abdomen and of tha in the stomach adhered together and healed, leaving an opening into the stomach of two and a half inches in diameter. At length a membrane was formed which shut down over it, like a valve, but did not adhere at the edges. This valve could at any time be pressed away, and the interior of the stomach and all its operations be exposed to view.

Dr. Beaumont employed this young man after his recovery, and performed a series of elaborate experiments on the circumstances which would produce a secretion of the gastric juice, the state of the interior surface of the stomach at the time, the effect of alcohol, tobacco, and spices on the secretion of this fluid, also the effect of exercise, occupation of mind, excited passion, etc. He appli d the stimulus of insoluble substances, put into the stomach to excite the secretion, and then removed it from the stomach to observe its action when applied to food in different conditions as to fineness, temperature, etc. He also instituted a full series of experiments upon the time required for the digestion of different kinds of food.

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199. *Of what elements does food ordinarily consist? Give instances of this*

It may be shown that most substances that we eat have a similarly complex composition. The object of stomach digestion is to separate that which is food from that which is not, and then to render soluble and actually dissolve the nutritive elements. To do this is the function of the gastric juice. The daily amount of this secretion may be put down at fourteen pounds. The active principle of the gastric juice is a peculiar substance called **pepsine**, a nitrogen compound, not unlike the nutritive food. It seems to be part of the mucous coat of the stomach in the process of decomposition. When slightly acidulated, as it is in the stomach, it tends to communicate the same change to similarly constituted bodies with which it comes in contact. Instances of this kind are of frequent occurrence. Vegetable substances, apples for example, beginning to decay, will communicate to others that are sound the same change; that is, they will bring on decay. The action of yeast is to put in operation in the gluten of flour the same chemical changes which the yeast itself is undergoing. In the same way the pepsine of the gastric juice,[62] being a nitrogen compound in a state of change, will decompose the nitrogenized parts of the food in the

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[62] It would seem that some vital process not yet explained is necessary to give to the gastric juice its solvent power. The composition of it has been carefully ascertained, and efforts have been made to produce it artificially, but without success. If, however, a compound be formed resembling it in composition, and a small quantity of gastric juice be added (or a small piece of the stomach of a calf or ox), the whole will become capable of reducing alimentary substances to chyme.

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complex character. What is the object of stomach digestion? By what agent is this object effected? What is the daily amount of gastric juice secreted? What is the active principle in it? In what condition is it? Give other instances in which bodies in a state of decomposition communicate to other bodies the same action. How do the nutritive portions of the food pass out of the stomach? Do they at once become a part of the blood? How do the respiratory portions pass from the stomach?

stomach so far as to separate them from the non-nitrogenized parts and from the woody tissue, and convert them not only into a soluble state, but also into that particular state of solution in which they are capable of passing freely through membrane. In this state they are absorbed by the interior surface of the stomach, and introduced into the blood. Thus one of the objects of digestion is accomplished; that is, the nutritive elements of the food have been furnished to the circulation. But the respiratory elements pass on unchanged through the pyloric orifice into the duodenum.

200. The digestive system requires more care than any other, partly because of its general importance, but especially because our enjoyments depend so much upon it that we are in danger continually of overtasking it. The practical rules by which we should be governed in reference to it are, however, very simple, and the reasons for them easily comprehended. They relate to the materials of food, the amount required, the frequency with which it should be taken, and the conditions of the system favorable for its elaboration.

201. The kinds of food. The system requires considerable *diversity* of food. The most suitable food soon loses its relish if we are confined to it. There must be diversity at each meal, and successive meals must not be a repetition of the same diversity. Even slight changes in the mode of cooking or flavoring will do much toward rendering food palatable, and therefore nutritious.

202. We may not be able to assign reasons for the need

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200. Why does the digestive system require special care? To what four circumstances do the rules refer by which the diet is to be regulated?

201. What is the first rule in regard to kinds of food?

202. Why do we need both nutritive and respiratory food? Are they both contained in every variety of food? How is the deficiency supplied? In what proportions are the several kinds required?

of this general diversity, but there is obvious reason for the use of the *nutritive* and the *respiratory* kinds of food. Each has its special function, as will be shown in the chapter on respiration. Hence every variety of diet is made to contain both kinds. Nearly all of the articles of food contain both kinds, but if they do not, we instinctively supply the wanting kind. Thus, certain meats that are wanting in fat, are always eaten with gravy or other substance rich in fat. Many kinds of fish are fried in butter for the same reason. The butter that we eat with bread and other vegetable foods, the pork cooked with beans, the oil and yolk of egg employed as dressing for salad, etc., are not accidental combinations of food, but such as experience has taught us to be essential in furnishing the requisite materials for the wants of the system. It is believed that when our food contains two-tenths of nutritive material, one-tenth of fat, and seven-tenths of sugar and starch, it will best meet the ordinary demand; but these proportions must vary with occupation, temperature, and the peculiarities of individuals.

203. The additional inquiry may still be made, from what sources are we to obtain these nutritive and respiratory elements of food? We have seen that vegetable processes only can form those combinations of chemical elements which constitute food. But these combinations we may obtain in the form in which the vegetable leaves them, or as they have been transformed into animal food, into the substance of the oyster, the salmon, or the ox. The kind of food designed by the Creator for any kind of animal is best determined by examination of the peculiarities

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203. How are the kinds of food which are suitable for us indicated? What peculiarity of organization is referred to? What are its indications in regard to the food of man? What other parts of our structure indicate a mixed diet? Under what circumstances would a vegetable diet be appropriate? What class of persons require animal food?

of organization with which the animal has been furnished. One of these peculiarities of organization is the teeth, as indicating the kind of food required. The appropriate food of animals with canine teeth is flesh, while the absence of them indicates that flesh would be inappropriate. Thus, the dog has only canine teeth and the horse only incisors and molars. In man the three kinds are found, and it may be fairly inferred that both animal and vegetable food are appropriate. The apparatus of digestion, both in length and structure, is intermediate between the digestive apparatus of carnivorous and herbivorous animals, and indicates, therefore, a mixed diet.

It is probable that persons who put forth but little effort, either bodily or mental, may subsist on a vegetable diet, and enjoy perhaps better health than they would if they used animal food. But a person of whom much mental effort is required, or who is required to exert vigorous and protracted muscular effort, must depend in part upon animal food. Such is the obvious conclusion on theoretical grounds, and such is the conclusion deduced from a wide generalization of facts in experience. The successful student must have animal food. The soldier, meeting hardship and exposure, must have animal food. The hard-working man in the field or the shop requires animal food. To reject such food is altogether at variance with the teachings of both our structure and our experience.

204. But a wide range of choice is left when these conditions have been complied with. Our preferences and observation must then guide us. There is an endless diversity of taste, and each individual may, as a general rule, allow his own taste to determine his selection of different

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204. Beyond the general considerations, how are we to be guided in the selection of our food?

kinds of food; nature, however, furnishes us checks upon this selection. Some kinds of food are found to stimulate the secretions too much, particularly in the warm season, and bring on summer complaints; other kinds of food seem to check the secretions, and are not digested at all, but remain in the stomach till fermentation commences. Then either the gaseous eructations from the stomach, or portions of the food itself rising into the mouth, enable us to taste and recognize the kind of food which the stomach will not digest. Cheese, cabbage, fish, etc., are thus often pointed out to individuals as injurious. Each person may, then, follow his natural preferences in the selection of his food, subject, however, to such modifications as are suggested by his observation of the effects of particular articles of food. These principles, judiciously applied, will lead to very different rules for different persons, but still, for each one, such rules as it is safe for him to follow.[63]

205. There is, however, a diseased condition of the stomach constituting **dyspepsia**, in which the taste is scarcely reliable at all as a guide. The gastric juice is either sparingly secreted, or it is impaired in quality. It is necessary then to furnish such food as will, as far as possible, excite the mucous coat of the stomach to action. The covering of the kernels of grain, or any other substance which gives coarseness of texture, have this effect;

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[63] Persons who complain of being injured by particular kinds of food, often admit the soundness of these rules by saying that when they ate such and such articles they knew that they should be injured by them. The difficulty is not that the indications of nature are so obscure, but that we are so averse to following them.

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205. When is the taste not reliable as a guide? What is the first object to be secured in the food of dyspeptic persons? What kinds of food answer this purpose? What other property must the food possess? What kinds of food are to be rejected on this ground?

and hence bread made of unbolted flour is one of the most suitable forms of food for such persons. But it is also desirable that the food be easily digested; hence, rich pastries of all kinds are objectionable for such persons. New bread is also unsuitable, because, when eaten, it becomes an adhesive mass which does not allow the gastric juice to mingle readily with it. Hence, also, everything that tends to *preserve* substances, that is, to prevent spontaneous chemical changes, would also tend to prevent this particular chemical change, of which digestion consists. Hence, preserves, meat which has been salted, any substances which have been pickled, are suitable only for persons whose digestive powers are unimpaired and vigorous.

206. Perhaps, strictly speaking, there is no such thing as liquid food; still we often take food into the stomach in a liquid state. Milk, especially, is of this kind, but it separates before digestion into solid and liquid portions, and the solid portion, in which the nutriment consists, is subjected to the ordinary process of digestion. It is certain that the liquid portion of gruels and soups is also, in a great measure, absorbed before the nutritious part is digested, though it is not improbable that some of the nutritious portion is absorbed directly into the circulation, without going through the digestive process.

Liquid substances are, however, as much required in the system as solids, though we may not regard them as food. The blood requires a certain proportion of water to give it fluidity; and as it is every moment giving off water from the system by perspiration and by the breath, it is necessary that water be supplied in considerable quan-

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206. How is liquid food received into the system? Why does the system require liquids? How are they taken into the system? What objections exist to the use of tea and coffee? What circumstances would indicate that they may be used? Why are alcoholic drinks injurious?

tity. This is absorbed by the stomach, and received at once into the blood. It is taken either in the form of pure water or some modification of it, and generally in connection with our food. This practice of taking drink in connection with our food has sometimes been objected to, but it seems to be natural, and in harmony with the wants of the system.

Tea and coffee have often been objected to as affecting the system injuriously. They undoubtedly contain properties which, when taken to excess, have such effects, and if headache and want of energy result, when the stimulus of them is withdrawn, their use should be abandoned. They, however, contain, as their essential property, a compound of nitrogen, which is probably useful, and, with certain kinds of diet, may be essential to the health. When taken moderately, they doubtless encourage a healthy action of the stomach, and of the general system.

Alcohol, as a chemical compound, has nothing analogous to it in the system, and, so far as we know, never contributes anything toward the formation of any of the tissues of the body. It contains the elements of respiration, and it may tend to give fluidity to the blood, as water does; but it also possesses other properties which specially unfit the blood for its functions. Its principal effect in the system is as an excitant, and if it be admitted that the physician may sometimes avail himself of this property advantageously, its general effects in the community are such, that it would seem proper to forego any inconsiderable advantage which might, in extreme cases, attend its use, and banish it altogether.

207. There are several modifications which food undergoes in the process of cooking, which in some degree affect

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207. What changes does food undergo by cooking?

its character. It is not the chemical constitution but its physical character that is changed. Thus, in the cooking of vegetables the cohesion is diminished. When meat is boiled a part of the cellular membrane is dissolved, while the muscular fibre which lies within is unchanged. The baking of bread simply breaks the vesicles in which the farinaceous part is held. Thus, the mechanical obstacles to the digestive process, which exist in the substances used as food, are partially removed by the cooking process.

208. In connection with the cooking of food there are, however, several additions, such as salt, vinegar, mustard, and various spices. Some of these, particularly salt, are demanded in small quantity by the system. Others, without being absolutely necessary, may, by rendering food palatable, so far favor the secretion of the gastric juice, and their presence, in contact with the mucous membrane of the stomach, may stimulate it to activity; so that a moderate use of them is probably not deleterious. There is, however, no doubt but that the degree in which they are used is excessive, and, by over-stimulating the stomach, tends to weaken its power.

A degree of warmth to the food considerably above the ordinary temperature of surrounding objects, is also a healthy promoter of the digestive powers; but the injurious habit is often acquired of taking food, especially tea and coffee, so hot as to injure the organization of the tissues.

209. The quantity of food. From what has been said of the objects for which food is taken, it follows that the amount needed will be variable, depending upon the

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208. What are the effects of the several substances added in the cooking process to flavor food? How is the system affected by the temperature at which some articles of food are taken?

209. How is the proper quantity of food indicated?

effort put forth and the degree of exposure to which we are subjected. The demands of the appetite are the natural indication of the quantity needed. There is a period, at every meal, when the appetite is satisfied, and yet more food can be eaten without inconvenience or aversion. This indication of the appetite that the wants of the system are met, though not obtruding itself upon our notice, always exists, and may with attention be observed. After this period whatever is eaten is not because the system craves it, but because it gratifies the taste, and is likely to be injurious.

210. There are instances of a morbid appetite which it would be unsafe to follow; but there are always in connection with it other indications of disease, which leave us in no doubt that it is unnatural.

There are often complaints of want of appetite, but it is safe to follow this indication and abstain from food. A person seldom suffers from abstinence when there is no craving for food. Some of the best medicinal effects upon the system are produced by this abstinence. The want of appetite is the warning of nature not to lay upon the system at such times the task of digestion.

211. Times of taking food. The teaching of nature is to eat when we are hungry, but the desire for food is only periodical. It is undoubtedly best that we have stated times for eating, and eat only at those times. These periods should be often enough to meet the demands for repair, which are continually made by the system. The general practice of taking three meals a day is, probably, not objectionable, though some have contended that only two would be preferable.

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210 Is the appetite always a guide? What is the indication when there is a want of appetite?

211. How often should food be taken? What objection exists to taking food between our regular meals? What to eating in the evening just before retiring?

Lunches between meals cannot but be injurious. The stomach, like the organs of the body generally, requires periods of rest; when food is taken between meals, demands upon the stomach are made continually. For the same reason, the eating of fruit or confectionery, except at regular meals, is hurtful. The same objection lies against the habit of eating a short time before retiring. All of the involuntary powers are less energetic during sleep than when we are awake; digestion will therefore be feeble, the food will lie too long in the stomach, relish for the next meal will be diminished, and the power of the system to act upon it reduced. Besides these effects, dreaming is often induced, and thus sleep fails to refresh any of the powers of the system.

212. Conditions upon which digestion depends. As the gastric juice is the principal agent in effecting the necessary changes upon the food, the circumstances most favorable to digestion are those most favorable to the supply of this secretion. If the system is in a healthy state, whenever the stomach is suitably distended with food, and sufficient blood is supplied to it, the secretion will take place. Digestion will depend then, in the first place, upon an active circulation of the blood. This requires that there should be considerable exercise, but not of a character to exhaust or depress the powers of the system, and that there should be an abundant supply of pure air for respiration.

213. It is necessary, in the second place, that the blood be not deflected to other organs, but allowed to go to the stomach. This last condition is one very likely to be in-

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212. Upon what does digestion depend? Upon what does the secretion of the gastric juice depend? What are the conditions upon which an active circulation depends?

213. When there is active circulation, how may it be prevented from going in sufficient quantity to the stomach?

terfered with. Time should be allowed not only for eating but for digestion. The energy so characteristic of this country, drives the laborer from his meal at once to his work, the merchant to his counting-room, and the professional man to his office. There is no interval of rest during which the stomach can command the whole energy of the system in digestion; and hence it is not surprising that that function is so often impaired.

214. The mind may also be occupied involuntarily in such a way as to control the circulation and greatly interfere with digestion. Grief, melancholy, intense anxiety, all have this effect. Hence it is that travelling, visiting watering-places and the like, are often so serviceable. They divert the attention, and hence allow the circulation to resume its natural course, and to be employed in digestion whenever it is thus needed.

The conditions of the system most favorable to digestion are those in which there is neither physical exhaustion, ennui, nor mental depression, but such physical activity as to keep up a free circulation of the blood, buoyant spirits, and moderate mental activity, as in ordinary conversation.

Section III.—The Duodenum and Organs connected with it.

215. The duodenum (*p*, *e*, *i*, Fig. 93) (also 5, Fig. 94) is the commencement of the small intestine, from which it is distinguished by being more closely confined in its position, and by its not being connected with the spine by the mesentery. It arises from the stomach at the pyloric

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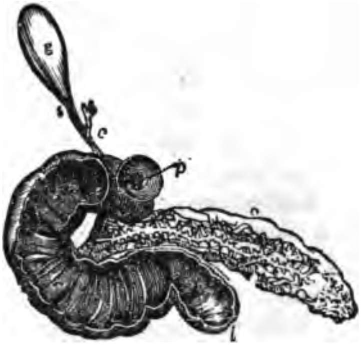
214. What is the effect of close application of mind upon the digestive process? What then are the conditions favorable to digestion?

***Section III.*—215.** Describe the duodenum.

Fig. 93.



e e The Duodenum. *p* The pyloric orifice of the stomach. *g* The bile sac. *c* The duct from the liver. *o* The pancreas.

orifice, and is from eight to ten inches in length. Like the stomach and the intestines, it is composed of three coats.

216. The liver (3, Fig. 94) is the largest gland of the body, and is situated on the right side of the abdomen, in contact with the diaphragm above, and with the pyloric portion of the stomach below. It receives a small artery by which its nourishment is conveyed to it. But it is supplied with a large amount of *venous blood.* It is the only gland which is supplied with venous blood, and a special arrangement of blood-vessels called the *portal* system is furnished which collects the *venous blood* from all of the other digestive organs and empties it into this gland. The bile is secreted from this blood, and is a slightly viscid fluid, greenish, bitter, and alkaline. There is a duct (*c*, Fig. 93) leading from the liver to the duodenum, and another from the bile sac (*g*) opening into it.

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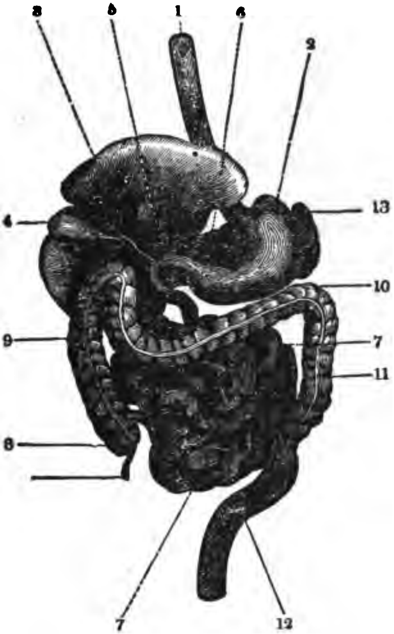
216. The liver. How is it supplied with blood? For what is the venous blood furnished? What are the properties of the bile? How is it disposed of during digestion and during the intervals?

Fig. 94.



The Digestive Organs. 1 The esophagus. 2 The stomach. 3 The liver. 4 The bile sac, its duct opening into the hepatic duct. 5 The duodenum. 6 The pancreas. 7 The small intestine. 8 to 12 The large intestine. 13 The spleen.

During digestion, the bile passes as it is secreted directly to the duodenum; but during the intervals of digestion, after filling the duct, it passes backward into the bile sac, and is retained until digestion again commences.

217. The average daily secretion of bile is about three and a half pounds. It consists mainly of two ingredients —the coloring matter, which is a merely refuse substance not again used in the system, and some oily materials,

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217. What is the amount of daily secretion of bile? What are its two chief ingredients? How is the saponaceous portion disposed of?

combined with soda, forming a peculiar variety of soap. This is reabsorbed as part of the chyle. Thus a portion of the bile becomes excrement, and to this end the liver is an organ for eliminating waste material from the body. The saponaceous portion goes again into the circulation, either as an economical use of material, or it may serve some useful purpose not fully understood in connection with the absorption of chyle.

218. The secretion of bile is from the portal blood, regarded simply as venous blood, but it also contains the nutritive elements of the food which have been absorbed by the stomach. The liver performs important changes upon this newly admitted portion of the portal blood. The general object seems to be to prepare it for being acted upon by the respired oxygen. Accordingly, it converts a portion of the new material into liver-sugar, a form of combustible food in the best condition for use in the lungs.[64] The blood-cells in a state of formation seem also

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[64] An intimate relation exists between the liver and the lungs In a cold climate we respire more oxygen than when the temperature is milder. The liver seems then to prepare all of the elements of respiration which the food furnishes for use in the lungs. Even then there may be not enough, and the oxygen acts upon the lungs themselves, inducing consumption. In warm climates, on the contrary, because of the diminished supply of oxygen, the respiratory food is not all used. The liver returns it to the intestines. It comes back to the liver, and is again returned. The liver becomes thus overtaxed and diseased. Hence the prevalence of pulmonary diseases in cold climates and of bilious diseases in warm climates.

The liver is larger in proportion as the lungs are smaller. In cold-blooded animals the respiration is very feeble and the liver very large. Such animals take a large amount of food at once, and are then subject to long fasts. The food is digested and furnished to the circulation. Passing many times through the liver, a portion is each time fitted by it for use in respiration. It is thus retained in the system until, by slow respiration, it is all consumed.

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218. Has the liver other functions besides secreting bile? What is the first change upon the new material in the liver? What other function of the liver?

to receive important additions in their passage through the liver.

219. The pancreas (*o*, Fig. 93) is a gland about six inches in length, situated behind the stomach and across the spine. It secretes a fluid resembling the saliva, which is conveyed by the pancreatic duct into the bile duct, and is thence emptied into the duodenum.

220. The amount of pancreatic fluid is two or three times as much as the bile, and has no other known agency except the change which it effects in the digestive process. The chyme as it enters the duodenum contains all of the oily, saccharine, and starchy ingredients of the food nearly unchanged. The action of the stomach has been to separate the nitrogenized compounds and introduce them into the portal blood. The pancreatic juice, influenced to great extent by its alkaline character, changes starch into sugar. Sugar, whether taken into the system as such or derived from the changes upon starch, is decomposed into lactic acid, and in this condition is readily absorbed.

221. The pancreatic juice, while it does not decompose the oily constituents of food, does bring them into the condition of an *emulsion*. This will be best understood by remembering that milk is essentially an emulsion. The water, which is its chief constituent, does not dissolve the butter, but it holds it suspended in particles of extreme minuteness, and it is only by long standing that the oily particles rise to the surface. The white color results from these suspended particles of oil. The pancreatic juice is capable of bringing into minute division the oily

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219. Describe the pancreas and its secretion.

220. What is the daily secretion from the pancreas? What are the constituents of the chyme? What is the action of the pancreatic secretion on starch? Upon sugar?

221. Upon the oleaginous portions of food? Give the illustration.

substances of the food, and holding them in this condition of an emulsion.

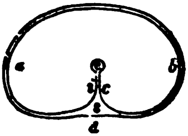
222. It is then the office of the pancreatic juice to bring into a condition suitable for absorption all of the respiratory elements of the food. The respiratory portion of the food, in this condition, is called *chyle*. It has a milk-like appearance, and consists of the useful portion of the bile, of an emulsion of the oily parts of the food, and of the starchy and saccharine parts, mostly in the form of lactic acid. There remains then only that part of the food which is incapable of being vitalized and appropriated. The two substances in this condition enter the small intestine.

Section IV.—The Intestines.

223. The small intestine (7, 7, Fig. 94) is a continuation of the duodenum, and is about five times the length of the body.

224. This intestine is supported by the peritoneum, which is the membrane that lines the cavity of the abdomen. When this membrane (*a*, Fig. 95) comes to the spine, *s*, it goes forward so as to inclose the intestine *e*, then returns to the spine and continues its course in the direction *b*. This duplicature of the peritoneum forms the outer coat of the intestine, and the double membrane between the intestine and the spine

Fig. 95.



Horizontal Section of the Abdomen. *a b* The peritoneum. *s* The spine. *e* The small intestine. *i c* The mesentery.

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222. What, then, is the function of the pancreatic juice? What is the product called? Of what does it consist?

***Section IV.*—223.** Describe the small intestine.

224. Describe the mesentery and lacteals.

is called the **mesentery**. A portion of the mesentery (2, 2, Fig. 96) is represented as supporting the intestine; and lacteal vessels (1, 1) come forward to the intestine, and probably open into it by capillary orifices.

225. The intestines are subject to a constant vermicular motion, by which their contents are made to move slowly through them. The particles of chyle, as they pass along the intestine, are gradually absorbed. The veins undoubtedly absorb, to considerable extent, those which are not oleaginous. These veins are feeders to the portal system. Thus all the products of stomach digestion and part of the products of intestinal digestion are subjected to the action of the liver before they pass to the heart and lungs. The lacteals absorb the remaining portions of the chyle.

226. The lacteals pass through small glands within the mesentery, and continue to unite as they approach the spine, where they form but one vessel (4), **the receptacle of the chyle**. This vessel forms a continuous tube up the spine, where it is called **the thoracic duct**, and opens into the vein (the descending vena cava, at 10) which collects the blood from the head and upper extremities.

227. The chyle, as it appears in the lacteals, contains also some nutritive elements, whether derived from the chyle in the intestine or absorbed from the contiguous blood-vessels. In fact, the oil globules seem to be coated with a substance of this kind. Some of these oil globules, in passing through the mesenteric glands, become incipient blood-cells, though they have not yet assumed the red color. It seems also that these glands convert some of

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225. How are the contents of the intestines kept in motion? How is the chyle disposed of? Describe the actions of the veins.

226. What is the function of the lacteals?

227. How is the chyle in the thoracic duct different from that which is found in the lacteals at their origin? How is the change made?

the nitrogenized material which passes through them into fibrine. So that the chyle, as it appears in the thoracic duct, contains both fibrine and incipient blood-cells.

228. We have seen that part of the new material from the food, as it passes through the liver, is converted into liver-sugar, and the new blood-cells undergo modification. The other part of the new material is changed in passing through the mesenteric glands, some into fibre, the source of muscular repair, some into blood-cells, and a portion remains in its oleaginous state. Thus all of the useful portion of the food, after digestion, passes through glands which impress important changes upon it,[65] making of the nitrogenized portions blood-cells and fibrine, and of the non-nitrogenized portions the substances best fitted to evolve animal heat. Thus we see where the greatest amounts of the material required in the system are elaborated. Exactly where the brain material and some other parts are formed has not yet been determined.

229. Thus we have traced the changes upon the food till it enters the veins. It is now a constituent of the

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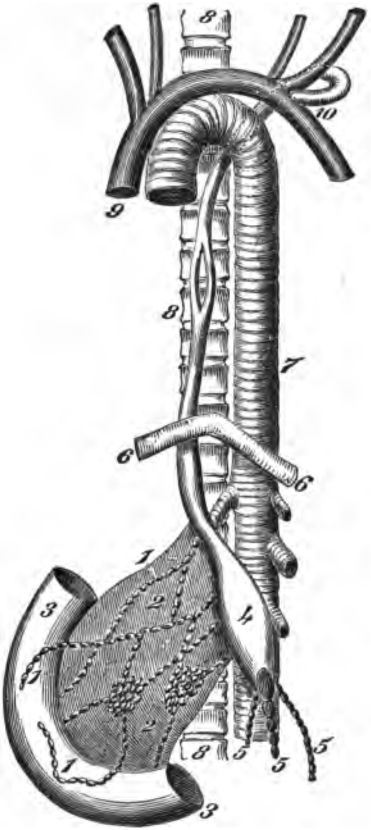
[65] It seems somewhat strange that the changes of the new portions of the blood in the liver are the formation of liver-sugar, a non-nitrogenized compound, though the nitrogenized food which had been digested by the stomach passes into the portal blood; and that the principal changes effected in the mesenteric glands are the formation of blood-cells and of fibrine, both nitrogenized compounds, though the materials seem to have been derived wholly from the digestion of non-nitrogenized food.

It may be said, in explanation, that only a very small part of the materials newly received into the blood need any change, and that in the great amount of absorption and secretion in the digestive tube there is not likely to be such a complete separation of the two kinds of food as a general description of the process would seem to indicate.

228. Is digestion the only modification which the food undergoes before it enters the blood? Is it known where all of the materials for repair are elaborated?

229. Is the useful portion of the food all transferred to the veins? Where must we look for any further changes upon it?

Fig. 96.



1, 1 Lacteals. 2, 2 Part of the mesentery containing mesenteric glands. 3, 3 Part of the small intestine. 4 The receptaculum chyli, continued upward as the thoracic duct, which opens into the descending vena cava at 10. 5, 5. 5 Lymphatic vessels opening into the receptaculum chyli. 6, 6 The diaphragm. 7 The aorta. 8 The spine. 9 The descending vena cava.

blood, and its further course must, therefore, belong to the circulating system.

230. The large intestine (8 to 12 inclusive, Fig. 94) is about one-fifth the length of the small intestine, but it has much greater capacity. The nutritious portion of the contents of the small intestine having been absorbed, the excrementitious portion is received by the large intestine, and, after being conveyed by a circuitous course, is expelled from the system.[66]

CHAPTER II.—OF THE CIRCULATION.

231. The circulating fluid is the **blood**. It contains the materials which are necessary for the formation of all the tissues of the body, such as brain, muscle, bone, etc., and those which are employed in the various repairs which the body requires; and we have seen how these materials are continually elaborated and furnished by the digestive process.

232. The amount of blood has been variously estimated, but twenty pounds is probably about its average weight.

233. If a portion of blood be taken from a vein and

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[66] The excrement is lodged in the large intestine to prevent the necessity of constant depletion; but scarcely anything is more important to health than that the feces be evacuated daily, and it is better that it should be at a particular hour. Persons whose habits are not active, and whose respiration is feeble, communicate but little mechanical motion to the abdomen, and the feces become hardened and may remain for days. This, however, cannot be without injury; the system should be required to conform to rule, and a constipated state of the intestines will then seldom occur.

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230. Describe the large intestine.

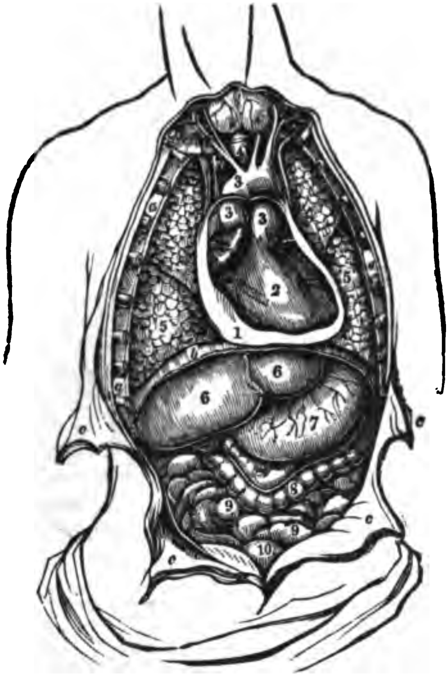
Chapter II.—231. What is the circulating fluid? What are its peculiarities which fit it for serving the purpose of nutrition? How does it receive the nutritious substance?

232. What is the amount of blood in the system?

233. What are the parts of which blood is composed?

allowed to stand for a short time, a part of it becomes watery and nearly colorless. This is the **serum**, upon which the liquidity of the blood depends. The clot or solid portion can be reduced by repeated washings to a stringy and nearly colorless mass, which is **fibrin**. This is the nutritious part. That which has been washed out consists of blood-cells, upon which the color of blood depends, and which is essential to the proper effect of respiration upon it.

Fig. 97.

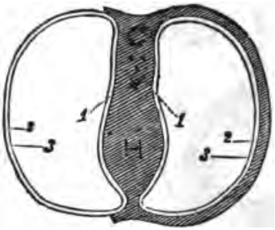


1 The pericardium. 2 The heart. 3, 3 Blood-vessels from the heart. 4 The trachea. 5 The lungs. 6 The liver. 7 The stomach. 8 The large intestine. 9, 10 The small intestine.

234. We may regard the organs of circulation as a simple hydraulic apparatus, designed to establish the motion of a liquid in a given direction, and through a given circuit. It must then contain a set of tubes in which the liquid is to be conveyed, so fitted with valves as to prevent the motion in one direction and allow it freely in the other, and means of exerting the force necessary to produce the required motions of the fluid. The heart, arteries, and veins are designed to fulfill these conditions.

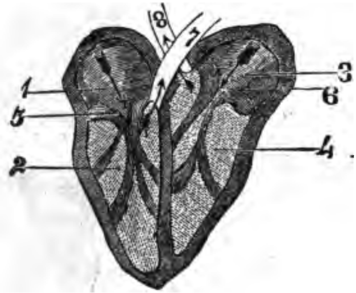
235. The heart (see lith. pl. IV., Fig. 1) is inclosed in a strong cellular substance (1, Fig. 97), called the pericardium, the inner surface of which supplies the lubricating fluid for the motions of the heart. The mediastinum is the double membrane which comes forward from the spinal column to the sternum, and divides the thorax into two cavities. The heart, with its pericardium, is situated between the two layers of the mediastinum (H, Fig. 98), en-

Fig. 98.



A Horizontal Section of the Thorax. The two membranes, 1, 1, constitute the mediastinum. 2, 2 The same membrane extends so as to line the cavity of the thorax, where it is the pleura costalis. 3, 3 The continuation of it, so as to cover the lungs, the pleura pulmonalis.

Fig. 99



1 The right auricle. 2 The right ventricle. 3 The left auricle. 4 The left ventricle. 5 The orifice from the right auricle to right ventricle. 6 The orifice from the left auricle to the left ventricle. 7 The pulmonary artery. 8 The aorta.

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234. What organs are necessary to constitute an apparatus for the circulation of the blood?

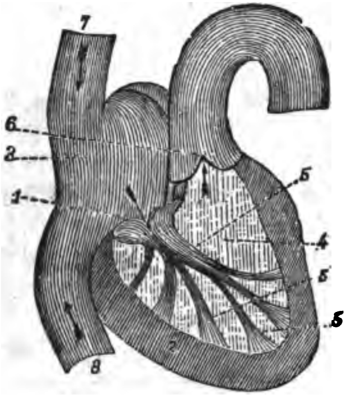
235. Describe the mediastinum. The pericardium. The position of the heart.

croaching more upon the cavity of the left side than the right, with its apex directed downward and resting on the diaphragm. (See lith. pl. III.)

236. The substance of the heart consists of a mass of muscular fibres, so arranged as to inclose four cavities. The first (1, Fig. 99) is the right auricle, and the second (2) is the right ventricle. The third cavity (3) is the left auricle, and the fourth (4) is the left ventricle. The auricles may be regarded as mere enlargements of the veins which bring the blood to the heart. The thick, strong muscular walls of the ventricles (2, Fig. 100) indicate that they are designed to give the principal force to the arterial circulation. Both ventricles contract at the same time.

237. The orifice (1, Fig. 100) from the auricle (3) to the

Fig. 100.



Valves of the Heart and Arteries. 1 The orifice between the auricle and ventricle. 2 The muscular walls of the ventricle. 3 The auricle. 4 The ventricle. 5, 5, 5 The fleshy and tendonous ligaments by which the valves of the heart are strengthened. 6 Valves of the arteries. 7 The descending vena cava. 8 The ascending vena cava.

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236. Give the structure of the heart.

237. Describe the valves of the heart.

ventricle (4) is furnished with membranous valves, which easily yield when the blood passes in the direction indicated by the arrow (at 1); but when the ventricle (4) contracts, they are prevented from yielding by fleshy and tendonous strings (5, 5) extending from them to the walls of the ventricle.[67] They, therefore, allow the blood to flow into the ventricle, but prevent its reflux. Those in the first ventricle are called the **tricuspid** valves; those in the second are the **mitral** valves.

238. **The arteries** are the strong cylindrical tubes which convey the blood from the ventricles. They are composed of an exterior coat of condensed cellular substance, upon which the strength of the artery principally depends, a middle coat of elastic membrane, with muscular fibres interspersed, upon which the contraction of the artery depends, and a third membrane, with a smooth interior surface, the object of which is to diminish the friction arising from the motion of the blood.

239. The arteries, as they arise from the heart, are each furnished with valves (6, Fig. 100), which are so constructed as to allow the blood to enter the arteries freely, but to prevent its going back into the ventricles. They are named the **semilunar** valves, and are the only ones which the arteries contain.

240. **The pulmonary artery** (12, pl. III) arises from the right ventricle, and is distributed to the lungs.

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[67] These strings, as stay ropes, not only support the valves, but they cause the blood and the chyle, which have just been emptied into it, by their rapid motion through the meshes thus formed, to be more thoroughly mingled together before going to the lungs.

238. The arteries.
239. The valves of the arteries.
240. The pulmonary artery.

241. The artery which arises from the left ventricle and is distributed to the body, is called the **aorta** (*a b*, pl. VI.) The first branches from the aorta are the **coronary** arteries, a small pair, which is distributed to the substance of the heart. The two **carotid** arteries (2) arise from the highest part of the arch of the aorta, and ascend along the neck to the base of the cranium, where they each divide into two portions, one of which supplies the brain and the other the face and the integuments of the head. The two **subclavian** arteries (3) also have their origin from the arch of the aorta, and supply the upper extremities. In its passage to the diaphragm, the aorta gives off small branches to the lungs and parietes of the thorax. Within the abdomen it gives off the **phrenic** artery (4), which is sent to the diaphragm, the **cœliac** artery (5), which supplies the liver and pancreas, the stomach and the spleen, the **mesenteric** artery (6), which goes to the intestines, and the **emulgent** artery (7), which goes to the kidneys. As the aorta enters the pelvis, it divides into the **iliac** arteries (8), which, after sending branches to supply the external and internal parts of the pelvis, are distributed through the inferior extremities.

242. The veins are the tubes by which the blood is returned from the different parts of the system to the right auricle of the heart. Like the arteries, they have three coats, but they are thinner and have less strength, though much greater capacity. They are furnished with a great number of valves (Fig. 101) in the different parts of their course. The veins have the same general distribution as the arteries (lith. pl. VII.). Those from the head, thorax, and upper extremities unite to form the **descending vena cava** (10, pl. III.). Those from the

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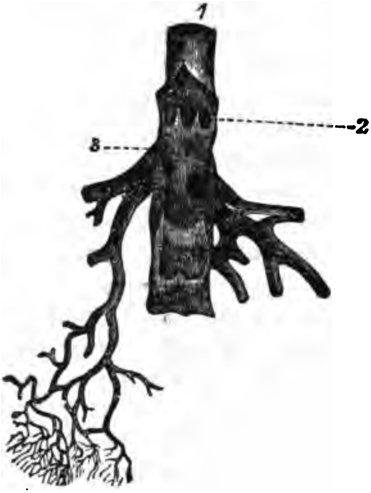
241. Describe the aorta and its branches.
242. Describe the veins.

Fig. 101.



1 A vein. In the lower part the vein laid open to show the numerous folds, 2, 2, of the inner coat of the vein which act as valves. 3 The opening of a branch into a larger vein.

abdomen and lower extremities unite to form the **ascending vena cava** (9). These two veins meet at the right auricle.

243. We may now trace **the blood in its course** through this system of vessels (lith. pl. V.). It will become more simple if we regard the first auricle and ventricle as constituting one heart, and the second auricle and ventricle as constituting a second heart. Such division actually exists in some animals. Let us commence with the blood, as it is collecting from every part of the system (*b*, *b*, *b*) into the veins. We find these veins all lead to and terminate in the first auricle (1), from which the first ventricle (2) receives it, and by contraction sends

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243. The course of the circulation.

it through the pulmonary artery into the lungs. The circulating fluid thus far has been dark blood. In the lungs it undergoes certain changes, and receives a florid color. It is then collected by the veins of the lungs and brought to the second auricle (3), from which the second ventricle (4) receives it, and by contraction sends it into the aorta to be distributed to all parts of the body, to be again collected by the veins. If we now regard these two hearts as brought together, and, to economize room, united into one organ, we shall have a correct idea of the human heart and of the circulation through the system.

244. There are several distinct **forces** by which the circulation is promoted. The various movements of the body must be incessantly compressing the veins; and, as the valves prevent a reflux of the blood, these motions must contribute to carry the venous blood toward the heart. The suction power of the right auricle, and perhaps a slight contraction of the veins, have been supposed to assist the venous circulation. But the enlargement of the thorax at each inspiration, as it causes the breath, so it causes the blood to enter the thoracic cavity. Moreover, the capillaries, by capillary attraction, draw the blood into them. Here the blood is changed, and then the capillaries have but little attraction for it. It is, therefore, allowed to pass on. This attraction is the principal force.

The arterial circulation is chiefly dependent upon the contraction of the heart. It is for this purpose that so large an amount of muscular power has been given to it. The arteries are also elastic and probably muscular. At each pulsation of the heart, the new blood which they receive stimulates them to contract, and thus each wave set in motion by the ventricle is closely followed by a con-

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244. What are the forces by which the venous circulation is sustained? How is the arterial circulation sustained?

traction of the artery, and the motion of the blood is perpetuated to the capillary vessels, and perhaps beyond them into the veins.

245. Without accurate calculation, we have very little idea of the *quantity* of blood thus sent through the system daily. The ventricle receives nearly two ounces of blood at each pulsation, which it discharges into the aorta about seventy-five times a minute, making nine pounds, or more than a gallon every minute, or two barrels an hour.

246. Whenever the artery lies near the surface, the wave produced by each contraction of the heart can be distinctly felt, constituting the **pulse.** Its frequency varies with the mental states,[68] the amount of exercise, the age, the sex, and the health. In young children, the beats are more than a hundred in a minute. The ordinary pulse of a healthy person in mature life is about seventy-five. In old age it may sink to fifty or less. But its most remarkable changes are those dependent upon the condition of the system. It is to the physician his most reliable indication of the degree and kind of diseased action.[69]

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[68] Hence those poetic expressions, "the heart leaps for joy," "melts with grief," "sinks within one," and "the blood curdles in the veins," are not altogether figurative.

[69] It is one of the remarkable instances of adaptation in the system, that the heart is so sensitive to the slightest changes in the state of the blood, that its mode of contracting, and its frequency, indicate the existence of disease in its very first stages, and yet the heart is not sensible in any degree to external contact. "Hervey had an extraordinary opportunity of showing this. A young nobleman, from disease, had the heart exposed so that it could even be handled while beating; and Hervey found, to his astonishment, that, unless his fingers came in contact with the

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245. What is the amount of blood circulated each hour?

246. How is the pulse produced? Upon what does its rapidity depend, and to what account is it put?

247. When a vein is severed, the walls easily collapse and a coagulum forms around the orifice and checks the loss of blood. But when an artery is severed, the elasticity prevents its collapsing, and the blood escapes in spirts. The loss of blood is often so rapid that it causes death in a short time. The first thing to be done then is, to close the artery mechanically till surgical aid can be obtained. Sometimes the thumb pressed hard upon an artery on the side of the wound, toward the heart, will be sufficient to check the blood. A handkerchief or other bandage may be placed around a limb which has been wounded, and drawn so closely that the pressure of a knot in it placed over the artery will be sufficient compression. Or a key slipped under the bandage and upon the artery may be used as a lever to compress the artery. But it may often be necessary to put the finger into the wound, find the end of the artery, and compress it there.

But a physician should, in such cases, always be called at once. We may succeed in checking the loss of blood for the time being, but the end of the artery must be taken up and tied with a ligature, in order to resist the elasticity of the artery and force of the circulation long enough for the artery to heal.

The danger to be apprehended from the wounding of an artery is sufficiently indicated by the fact, that they lie as far below the surface as they can be placed, and are

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outer skin, the young man was altogether unconscious of the heart being touched." Upon reflection, we see that it is entirely unnecessary that it should have the sense of feeling. Anything that would reach the heart would be likely to produce death, and hence the sense of feeling there would be no warning of danger, as it is at the surface.

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247. What practical rule is to be observed when an artery is wounded? How is the bleeding to be stopped? How is the artery to be ultimately secured?

otherwise guarded in various ways to protect them from injury. They are placed so near the surface that the pulse can be felt, only when it is impossible to have them lie deeper, as those on the head, or those which pass the wrist to go to the fingers.

248. When an artery has been severed, it might seem that the circulation in the part to which the artery is sent must be prevented. But provision is made for such cases by the *anastomosing* of the arteries. Thus, if the principal artery of the arm or leg were taken up (at 9 or 10, pl. VI.), the small anastomosing arteries (11 or 12) would still carry blood to the part beyond, and they would soon enlarge so as to furnish a competent supply.

249. The blood is subject to two distinct *circulations*, one through the lungs, which may be called the pulmonary circulation, the object of which is to effect certain changes in its constitution; and another, much more extensive, through the various parts of the body. The object of this is the nutrition of the system, and may be called the nutritive circulation.

250. The *amount* of the change effected by *nutrition* is greater than is generally supposed. The quantity of food taken is no measure of it whatever. The various secretions into the joints, the cranium, the abdomen, the stomach, and other parts of the digestive canal, as well as throughout the solid parts of the body, are generally regarded as secretions directly from the blood; but it is by no means certain that they are not produced by the

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248. When an artery has been severed, how is the circulation beyond that point continued?

249. What are the two circulations to which the blood is subject?

250. Why is the amount of nutrition not measured by the amount of nutriment contained in the food? What idea of the amount of repairing done in the system do we get from the amount and character of the fluid circulated? How often does the body undergo an entire change?

metamorphosis of the tissues. It is at least certain that in various parts of the system there are portions of the tissues which lose their vitality, but which have not, by so doing, been rendered henceforth useless. On the contrary, they go either directly into the blood, through the absorbent system, or they are passed into the digestive canal, to be re-digested and sent again into the circulation. The amount of nutritive substance in the food which is eaten daily, is only equal to the amount of material which has been subject to such changes that it cannot be used again, and which, therefore, needs to be rejected from the system and have its place supplied by new material.

Some idea of the amount of taking down and building up which is done in the system may be gathered from the amount of blood which traverses the blood-vessels, which is not less than six tons a day. Its color has been changed, and the chemical constitution has been modified to an appreciable extent by materials which have been added to it from the wear of the system. But the amount of removal has been at least equalled by the amount of new structure erected.

Hence we see that our bodies are being taken down and built up; that is, they are subjected to change very rapidly. The bones, cartilages, ligaments, and tendons change much less rapidly than the soft parts; yet the body has probably been wholly taken down and rebuilt several times before a person reaches the age of twenty years.[70]

251. This process of nutrition takes place wholly in the

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[70] It has been thought that the body undergoes an entire change once in about seven years. Some parts are, however, changed hundreds of times within that period, and possibly some particles may never be changed; the change in the more solid parts must also be much more rapid in early than in advanced life.

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251. Where does nutrition take place? How are these capillary vessels proved to exist To what variation are they subject?

capillary system; that is, in those minute tubes, too minute to be traced by the eye, which go from the extremities of the arteries to the commencement of the veins. Such a connection is proved to exist, by the fact that the veins can be filled with mercury by injection through the arteries. Though the diameter of these tubes cannot be measured, yet we know that it is subject to considerable variation, and that their size in a great degree affects nutrition. Thus the enlivening emotions at once manifest themselves by the flush on the face; that is, by the enlargement of the capillaries to such a size that they will admit the red cells of the blood. Fear and other depressing emotions at once contract the capillaries, producing paleness, and nutrition is almost wholly suspended. It is likewise, in a great measure, suspended by exposure of the surface to a disagreeable or painful degree of cold. The capillaries may become so much enlarged as to constitute disease (inflammation). Cold water, or other cold applications, tend to reduce inflammation, because they tend to contract the capillaries.

252. Wherever growth is required, or waste has taken place, there the proper elements are taken from the blood in its passage through the capillaries, and deposited for the purpose of increase or repair. The selection of elements from the blood adapted to the formation of particular tissues, their removal from the capillary vessels, and their incorporation into the different organs, cannot be explained upon any known physical principles. These processes are, however, going on constantly and with rapidity; and yet, as a general rule, all this is done without mistake as to place, or to the kind or the amount of repairs required. We can only refer these changes to the constant,

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252. What are the three processes in which nutrition consists? Upon what principle are these processes explained? To what must they be referred?

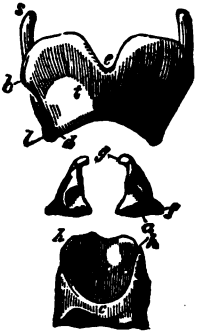
efficient, and beneficent presence of an unseen and divine Power.

CHAPTER III.—OF RESPIRATION.

253. The respiratory functions are performed principally in the thorax. We have seen that there is a vertical partition stretched between the spine and the sternum, called the mediastinum, which divides the thorax into two chambers (Fig. 98). The membrane which forms the mediastinum also extends round the sides of the thorax, forming a complete lining (2, 2) to each chamber, and is then reflected over the surface (3, 3) of the lung. It is called the **pleura.**

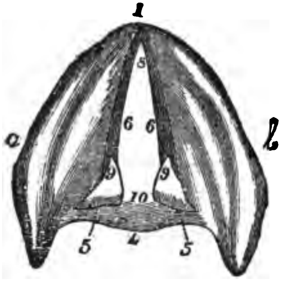
254. The organs of respiration are, the larynx, trachea, and lungs. The **larynx** (Fig. 102) is composed of five

Fig. 102.



The Cartilages of the Larynx. *c h* The cricoid cartilage. *g* The arytenoid cartilages. *t* The thyroid cartilage.

Fig. 103.



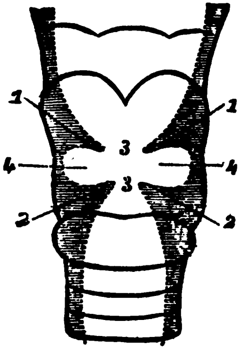
1 The front part of the larynx. 4 The posterior part of the cricoid cartilage. 5, 5 The arytenoid cartilages. 6. 6 The vocal cords. 9 The attachment of the cords to the arytenoid cartilages. 8, 10 The aperture called the glottis.

Chapter III.—253. Describe the pleura.

254. What are the organs of respiration? Describe the several cartilages of the larynx. The vocal cords. How is the voice produced? Upon what do its modifications depend?

cartilages. The lowest is a circular ring (*c, h*), called the cricoid cartilage. The thyroid cartilage (*t*) consists of two parts, united at an acute angle so as to form the prominent point in the neck (called Adam's apple). This cartilage is situated above the cricoid, so that in front there is a membranous space between them.[71] But as the two parts of the thyroid extend backward, they also become prolonged downward, so as to inclose the cricoid at the sides where they articulate with it. The cricoid is widened behind, and upon the upper edge of this widened portion (*h, h*) are placed the two arytenoid cartilages (*g*). From the base of the arytenoid cartilages (5, 5, Fig. 103) ligaments (6, 6) called the inferior **vocal cords** stretch forward to the front angle of the thyroid cartilage, reducing the dimensions of the tube, and giving the aperture a triangular form. There are two ligaments commencing near the top of the arytenoid cartilages, and running parallel with the lower ones, which are the superior vocal cords. A vertical section of the larynx, from *a* to *b*, Fig. 103, would be represented by Fig. 104, in which 1, 1 are the superior, and 2, 2 are the inferior cords, and 4, 4 are the **ventricles** of the larynx. The arytenoid cartilages are so furnished with muscles that they are capable of considerable motion; and, as one end of the cords 2, 2 is attached to them, it follows that

Fig. 104.



1, 1 The upper vocal cords. 2, 2 The lower vocal cords. 3, 3 The glottis. 4, 4 The ventricles of the larynx.

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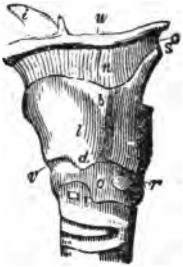
[71] This small membranous space can be felt below the Adam's apple, in the front of the neck, and thus the position of both the thyroid and cricoid cartilages will be ascertained.

they may be made tight or loose, or be made to approach or recede from each other. The voice is made by the air from the lungs passing these cords, and its variations of tone depend on their adjustment. But it is subject to various modifications, from the capacity of the lungs, the force with which the air is emitted, from the form and size of the mouth, from the nose, the lips, the tongue, the teeth, etc. The tube thus formed is suspended from the os hyoides (*u*, Fig. 105) by a membrane, *n*. The fifth cartilage of the larynx (*i*) is the epiglottis, so placed as to fit like a lid over the opening between the superior vocal cords during deglutition, and prevent food from entering the larynx.

Fig. 105.



The Larynx. *i* The epiglottis. *u* The hyoid bone. *l* The thyroid cartilages. *n* The membrane extending from the hyoid bone to the thyroid cartilage.

255. The trachea (4, pl. III.) is the continuation of the larynx to the thorax. It is composed of from sixteen to twenty rings of cartilage, which, however, do not extend entirely around the trachea, but leave a space behind, which is closed by membrane, and the rings are also attached to each other by membrane. Immediately behind the first bone of the sternum, the trachea divides into two branches (5, 6) called **bronchi,** which go to the two lungs.

256. The lungs (1, 1, 2, 2, pl. III.) are situated in the two cavities of the thorax. The left lung is composed of two lobes, and the right lung of three. Each lobe consists of a great number of divisions, called lobules. Each lobule is a congeries of air-cells, consisting of very delicate cellular membrane. The bronchi, after entering the lungs, divide into small tubes, and one of these tubes opens into

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255. Describe the trachea.
256. The lungs.

each lobule. All of the air-cells in a lobule communicate with each other, but there is no communication between the air-cells of different lobules.

257. We have seen that the blood is subject to two distinct circulations, one of which is through the lungs. It reaches the lungs by the pulmonary artery, which is subjected to exceedingly minute division, and finally becomes a system of capillary vessels, which are distributed upon the membranes composing the air-cells. (13, lith. pl. III.) The pulmonary veins receive the blood from these capillaries and convey it back to the heart. The lungs are, therefore, composed of air-cells, bronchial tubes, arteries, and veins."[72]

258. Respiration consists in receiving air into the lungs, and expelling it from them. This is effected by the alternate contraction and enlargement of the cavity of the thorax; and this change is performed by appropriate muscles, and not by any power belonging to the lungs. The thorax may be enlarged in three directions. The diaphragm has the form of a compressed dome (4, 4, Fig. 106), and the contraction of its fibres tends to depress the dome, and reduce its position to 2, 2. The depth of the thorax is thus increased. The ribs come obliquely forward and downward from the spine, so that their anterior extremities meet the line 2, 2, Fig. 107. There are several sets of muscles (8, 8) so attached to the ribs, that their contraction will raise them to a position nearly horizontal, and their extremities will be brought forward to the line 3, 3; that is, the transverse diameter of the thorax will

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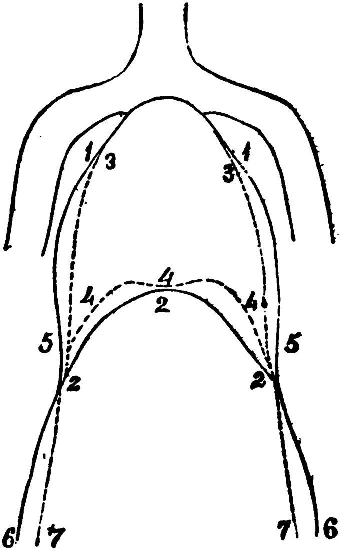
[72] The parts of the lungs here described are those upon which the respiratory functions depend. In addition, the lungs, like all other parts of the body, have their nerves, absorbents, and blood-vessels for nutrition. The interior surface of all the bronchial tubes and of the air-cells is also lined with a mucous membrane, which becomes important from its extreme liability to take on disease. In a condition of health, the secretion from this membrane is only sufficient to keep the surfaces moist, and is constantly removed by evaporation. But when inflammation sets in, the secretion becomes copious, and either frothy or thick and adhesive, according to the stage and degree of the inflammation, and is thrown off by expectoration. The intensity of the inflammation may vary from that of the slightest cold to that of active suppuration.

257. The pulmonary capillaries. Of what are the lungs composed?

258. In what does respiration consist? How is this effected? How is the vertical measure of the thorax increased? The transverse diameter? The distance from the spine to the sternum? What are the means of ordinary, and what of labored, respiration?

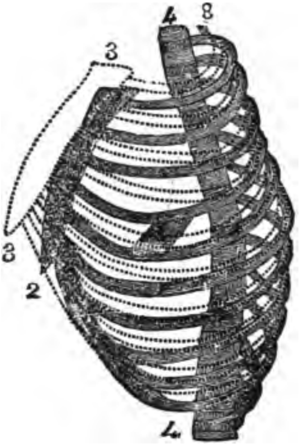
Fig. 106.



A Front View of the Thorax in Respiration. Air is drawn into the lungs by the compression of the diaphragm to the line 2, 2. At the same time the sides of the thorax take the position 1, 5. Air is expelled from the lungs by diminishing the cavity of the thorax. This is effected in part by compressing the sides to the dotted line 3, 4. In part, also, by compressing the abdomen from 6 to 7, thus elevating the stomach and liver, and lifting the diaphragm to the dotted line 4, 4.

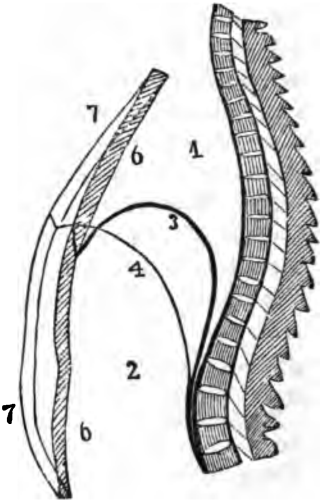
be increased. The sides of the thorax will then have the position 1, 5, Fig. 106, instead of 3, 4. At the same time the sternum will be thrown forward, so as to occupy the position 7, 7, Fig. 108, instead of 6, 6, which it does when the thorax is contracted.

Fig. 107.



1, 1 The ribs. 2, 2 The sternum in the position which it takes in *expiration*. The ribs are raised during *inspiration*, so that the sternum is brought forward to 3, 3. 4, 4 The spine. 8, 8 Muscles by which the ribs are raised at inspiration.

Fig. 108.



Side View of the Thorax. 1 The cavity of the thorax. 2 The cavity of the abdomen. 3 and 4 The different positions of the diaphragm in expiration and inspiration. 6, 6 and 7, 7 The different positions of the sternum and abdomen

In ordinary respiration, the diaphragm is the principal agent.[73] But in forced respiration, nearly all of the muscles of the neck, thorax, and abdomen are employed.

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[73] This action of the diaphragm is intimately connected with digestion. The depression of this muscle can take place only as the muscles of the abdomen are relaxed, to make room for the abdominal viscera: hence the

259. The amount of air received into the lungs at each inspiration is about one pint. But this will vary at different times in the same individual. Thus, vigorous exercise induces much fuller inspirations than are needed when we are at rest. The danger ordinarily is, that the amount will be below the wants of the system. This may result from the thorax being contracted naturally, or by the compression which it has received from the closeness with which clothes are worn, from the habit of sitting or walking with the shoulders bent over and resting upon the thorax, or from a diseased condition of the lungs.

260. Mental states also have an influence upon the amount of respiration. Depression of spirits diminishes the action of the respiratory muscles; and hence the deep inspirations (*sighing*) to which such persons are accus-

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difficulty of breathing after a hearty dinner, when all of the relaxation of the muscles is required to make room for the distension of the stomach.

The diaphragm rises in consequence of the contraction of the abdominal muscles pressing the viscera upward against it. Thus, the process of respiration cannot be carried on at all without giving constantly to the stomach and intestines the motion upon which the digestive process in a great measure depends.

It should not be inferred that ordinarily there is no elevation and depression of the ribs in respiration, for every person can see, by observing his own breathing, that there is. Still the object of this means of respiration seems specially designed to supply an extra amount, either when, from active or fatiguing exercise, the system demands an increased influence from respiration, or when, from the air being less pure, a greater amount is needed. Hence, persons who receive a sufficient supply, when the air is pure, become faint on entering a crowded room, if they are so dressed that their respiration cannot, by the movement of the ribs, be increased.

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259. What amount of air is ordinarily received into the lungs? Upon what does the variation from this amount depend?

260. How do the states of mind affect the amount of respiration? What is the physiology of yawning?

tomed. Nature thus insists upon these deep inspirations occasionally, to prevent in part the evils which would otherwise arise from the too limited amount of air which the lungs are receiving.

Yawning is for a similar purpose. It generally occurs either in the morning, before the respiratory muscles have received the amount of stimulus which, in a waking state, they need, or at other times when the body is sluggish and the respiratory action is feeble. It consists of an involuntary, deep, and prolonged inspiration, in order to completely fill the lungs, and furnish the necessary stimulus when a person is not disposed to secure it by active exercise.

261. The object for which air is introduced into the lungs is to supply oxygen to the blood. But if pure oxygen is breathed, the stimulus is too great. The atmosphere which has been provided for our use in respiration contains one-fifth of its volume of oxygen, and the most of the remaining four-fifths is nitrogen, which, so far as is yet known, has no other end than to dilute the oxygen so as to adapt it to the purposes of the system.

Assuming that the oxygen contained in a pint of air at the ordinary temperature, is the amount needed by the blood at each inspiration, it is obvious that when the air is reduced in volume by cold, a pint will contain more than we are supposed to need; and when it becomes expanded by a high temperature, it will contain less. The quantity of oxygen received into the lungs may vary from this cause by as much as one-fourth of the whole amount.

As the consumption of oxygen is connected with the development of the vital force, we see in this a reason

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261. For what purpose is the air received into the lungs? What is the constitution of atmospheric air? To what extent may changes of temperature vary the amount of oxygen inhaled? Why is more energy of the system experienced and more animal heat developed in winter than in summer?

why we should, in winter, experience more elasticity of feeling, possess more energy, and be able to perform more labor. Vital heat is also developed in connection with the consumption of oxygen. As a larger amount of heat is needed by the system in winter than in summer, it is a wise provision that a larger amount of oxygen is then necessarily inhaled.

262. The air may lose, to some extent, its fitness for respiration by being diluted with other substances, such, for instance, as watery vapor, but especially by carbonic acid.

A very small proportion of carbonic acid, about a tenth of one per cent., always exists in the air, and does not appear to be injurious; but, in various ways, it is liable to accumulate in larger quantity, chiefly, however, by respiration. If, by means of a tube, we breathe into a transparent solution of lime, it will at once become milky, and a chalky substance will at length subside. This, like common limestone or chalk, is carbonate of lime, of which the lime was dissolved in the water, and the carbonic acid must have come from the lungs. It is one of the essential products of respiration. It is injurious, not simply because it dilutes the air, and thus diminishes the proportion of free oxygen, for even when oxygen is added artificially, the presence of carbonic acid renders it detrimental. Four per cent. of this gas, which is about the proportion contained in the air as it comes from the lungs, renders it highly injurious, and a much smaller proportion is undoubtedly hurtful. In this fact principally consists the importance of proper ventilation of school-houses, work-

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262. How may the air lose, to some extent, its fitness for respiration? How is it shown that carbonic acid is exhaled from the lungs? What proportion of carbonic acid does the exhaled air contain? Does the injury to the air from the presence of carbonic acid arise from its reducing the amount of free oxygen? Why should places in which many persons are likely to be collected be well ventilated?

shops, churches, halls for public meetings, and sleeping apartments.[74]

263. The air is received into the air-cells (4, 4 pl. IV., Fig. 2) in the lungs, and the blood flows through the blood-vessels which are spread out over the surface of these cells. There is, therefore, a membranous partition between the blood and the air. Membrane is not, however, as was formerly supposed, impermeable to air, or even to liquids; but some gaseous substances penetrate it much more readily than others. Oxygen, carbonic acid, and watery vapor are found to be of the first kind, while nitrogen scarcely passes through membrane at all. It follows that, when atmospheric air is received into the lungs, the oxygen will readily pass from the air-cells into the blood,

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[74] The sleeping apartment has sometimes been warmed by setting a dish of burning charcoal within it. The casualties arising from this practice have, it is hoped, put an end to it. It is obvious that it must be attended with great danger, for carbonic acid is rapidly given off from burning charcoal, and the danger is increased from the fact that this gas tends to produce stupidity and sleep, and therefore furnishes to the individual no warning of its effects.

The large fireplace and chimney of former times had its advantages; for, with a good draught, the amount of air carried from a room by it was always sufficient to accomplish all of the purposes of ventilation.

When the draught is imperfect, carbonic acid may be thrown from a grate of ignited coal into a room in such quantity as, without producing any smoke, to bring on headache, and make the air very unwholesome.

The use of air-tight stoves has this disadvantage, that they effect no change of air in a room. They can be safe only when the air is frequently changed by opening doors or windows.

The objection to ventilation is, that in cold weather it introduces cold air, and with it exposure to cold. This objection is obviated in the use of furnaces. The air should be allowed to escape at the top of the room, and the air which is admitted is that upon which the warmth of the room depends.

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263. How does the oxygen reach the blood in the lungs? Why does not the nitrogen also enter the circulation?

while the nitrogen will be retained, and that carbonic acid and watery vapor will easily pass from the blood into the air-cells and be expired.

264. There are about twenty respiratory movements in a minute, and one pint of atmospheric air is inhaled each time. One-fifth of the atmosphere is oxygen; and it is found that about one-fourth of the oxygen, that is, one-twentieth of the whole amount of inspired air, disappears at each respiration, and nearly an equal volume of carbonic acid is supplied. By twenty respiratory movements, then, that is, every minute, a pint of oxygen is received into the circulation, and during the same time nine pints of blood (245) have circulated through the lungs. The blood, therefore, absorbs one-ninth of its volume of oxygen from the atmosphere.

265. We may now inquire what are the changes in the constitution of the blood effected by respiration? We have seen that the blood which comes to the lungs has a dark-red or purple color (243), and that when it goes from the lungs it has acquired a scarlet hue. In the lungs, the blood parts with carbonic acid and absorbs oxygen. These are all of the changes of importance known to occur; and we might infer that in these changes consists the conversion of venous to arterial blood. We can, however, subject venous blood to more direct experiment, by taking it from the system and exposing it to the action of the atmosphere, under such circumstances as to exclude the influence of other causes. It is still found to take the color of arterial blood, while oxygen is absorbed and carbonic acid is given off. The blood seems to undergo no change in chemical

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264. What proportion of its volume of oxygen does the blood take up? Give the calculation upon which this statement is made.

265. What changes does the blood undergo in the pulmonary capillaries by respiration? How may the proof be given out of the body? What changes take place in the nutritive capillaries?

constitution after leaving the pulmonary capillaries, till it reaches the nutritive capillaries, and none after it enters the veins till it reaches the lungs. Hence, the changes which take place in the nutritive capillaries must be exactly the reverse of those in the lungs; that is, the blood must part with oxygen and absorb carbonic acid.

266. The blood contains a small proportion of iron, amounting in the whole system to one or two ounces. This is found in the blood-cells. The most satisfactory explanation of these changes (which is, however, to a great extent hypothetical) consists in supposing that in the arterial blood the iron is in the state of a peroxide; that is, it is combined with one equivalent and a half of oxygen. In its circulation through the nutritive capillaries it meets with carbon, with which half an equivalent of its oxygen combines, forming carbonic acid. The iron is then reduced to the state of a protoxide. The carbonic acid combines with the protoxide, forming a carbonate of the protoxide of iron. This carbonate gives to the blood its venous character, and as such it leaves the capillaries and enters the veins. When the blood reaches the lungs, the oxygen there received decomposes this carbonate, sets the carbonic acid free, which escapes in respiration, and combines with the iron, restoring it again to the state of a peroxide. If this view is correct, the office of the blood-cells is that of carriers, distributing the oxygen from the lungs to every part of the body to which the circulating fluid is sent, and gathering up the refuse carbon and conveying it to the lungs to be eliminated.

267. It remains to determine the purposes for which these changes take place.

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266. Give the changes which are supposed to take place in the blood-cells.

267. What is meant by the vital force? Why can this not be considered as some other known force (as electricity, for example) acting to prevent the chemical changes?

The nutritious substances are highly complex compounds, such as are produced only by the processes of vegetable life, and are held together by a very feeble affinity. Whenever they become deprived of life, decomposition at once begins. We see this in the spontaneous decay of meats, fruits, vegetables, and even wood. But as long as they possess vitality, there is a power which resists this tendency to decay. We cannot make use of any other known power, such as heat, electricity, cohesion, or gravitation, to produce these results. We therefore give it a distinct designation—the **vital force**.

268. We have seen that, at short intervals, a certain amount of nutritious substance must be supplied to the blood. Before it enters the system, it is identical in composition with living tissue.[76] It therefore brings into the system the force by which it retains its complex composition. It passes without change of chemical constitution through the digestive apparatus, and through the organs of circulation. In the nutritive capillaries, it is simply removed from the circulation and incorporated into muscular and other tissues. The first change in the constitution of the nutritious substance takes place in the nutritive capillaries, by the combination of the oxygen which the blood-cells convey with the carbon of the living tissues. We must conclude, then, that this current of oxygen which enters the system by respiration, has for its object the decomposition (the destruction of vitality) of parts of the living body.

[76] It is not intended to convey the idea that the several tissues, such as muscle, membrane, cartilage, nerve, and brain, are identical in composition; but so nearly identical that, in order to give a correct *general view* of the several vital processes, they may be so considered.

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268. What change is effected in the nutritive capillaries by the oxygen of the blood-cells? How does the vital force become available? How is it used? What part of it can be employed in voluntary effort?

But when this decomposition takes place, it liberates the vital force by which the combination was before retained. And this force, no longer employed in the service of the nutritious substance, now becomes available for other purposes. The system *claims* the involuntary motions, such as those of nutrition, respiration, digestion, the contraction of the heart, etc.; and the brain controls and appropriates enough force for this purpose, whether we assent to it or not. The surplus of this force we are at liberty to employ in thought, exercise, labor, etc., at our option. This is a man's physical strength.

269. This explanation of the mechanical power of the system is in accordance with all of the known facts which bear upon it.

Thus, if a person breathes impure air, or has a contracted chest, so that but a limited amount of oxygen is inhaled, but little tissue can be decomposed, and his muscular powers are in the same proportion enfeebled.

If a person be confined to a scanty diet, but little living tissue will be formed. But little, therefore, can be decomposed, and his ability to perform physical labor is correspondingly reduced.

When a person puts forth an extraordinary degree of muscular effort, a large amount of decomposition must take place, and a large amount of nutrition is required. Hence it is, that whenever an unusual amount of muscular effort is demanded, the respiratory effort is increased, and the amount of air inhaled is increased two or three fold. The immediate effect is the increased decomposition of living tissue and the increased supply of physical power.

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269. What is the effect of limited supply of oxygen, and why? What of limited supply of food, and why? What conditions are neccessary where great muscular effort is required? What is the effect of rapid growth upon the strength, and why? In what consists the demand for sleep? How does vitality cease from starvation?

A large amount of nutriment may be taken into the system, but may be used principally to promote **growth**. As there is but a small proportion of it decomposed, there is but little muscular power or ability to endure fatigue.

It would seem that the system is incapable of renewing these tissues as rapidly as they are decomposed by the system in an active condition. Hence it is made necessary that most of the mechanical functions should be periodically suspended, and respiration become less active. This is the period of **sleep**, and only so much mechanical force is employed as is necessary to carry on the circulation and reconstruct the tissues in which the decomposition was becoming excessive.

When the decomposition of tissue goes on, and furnishes the force necessary to perform the vital functions, and there is no supply of food from which new tissue can be formed, extreme emaciation takes place. When there is no tissue left which is capable of decomposition, the vital force can no longer be developed, and life no longer exist; such is death by **starvation.**

270. We have seen that one effect of the combination of oxygen with these tissues is, to convert the vital force into available mechanical force. Another effect must be the development of **heat.** The changes are as strictly a combustion as if they took place in the open air—of precisely the same nature as the combustion of ordinary fuel. They consist essentially in the combination of oxygen and carbon; and it is one of the necessary results of this combination to generate heat.

In ordinary combustion carbon is supplied in the form of wood or coal; the oxygen is derived from the air; car-

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270. What other effect besides the development of vital force results from these chemical changes? Compare these changes with ordinary combustion. How is the amount of heat limited? Where is it produced?

bonic acid is formed and removed by the current of air; a residual ash of earthy matter with which oxygen will not combine is left, and heat is evolved. Within the system, the fuel is the living tissue, the oxygen is furnished by the red blood-cells; carbonic acid is produced by the combination, removed by the venous blood, and at length exhaled from the lungs; a residual substance with which oxygen will not combine is dissolved in the blood, but finally removed by the action of the kidneys, and heat is evolved.

The amount of heat evolved must be in exact proportion to the carbon consumed, and depends, therefore, upon the amount of oxygen inhaled. The heat will be evolved, not in the lungs particularly, but in every part of the system to which the oxygen is carried by the blood-cells.

271. We have thus far spoken of the food as composed of nutritious substances; that is, of substances which are identical in composition with the tissues of the body, and which, in order to effect the nutrition of the system, need only be rendered soluble by the digestive process, introduced into the circulating fluid, and appropriated to the repairs and growth of the several parts. All of these substances consist essentially of four elements—oxygen, hydrogen, carbon, and nitrogen."[76] They are called **the elements of nutrition**, or, as they are characterized by containing nitrogen, they may be called the **nitrogenized constituents** of the food.

The flesh of animals, cheese, and eggs consist almost entirely of these elements. The albuminous vegetables, such as beans, peas, etc., and the gluten of wheat and other grains, contain them in large proportion. Most other vegetable substances — the grasses, roots, etc. — contain them, but in smaller proportion.

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[76] There are various other substances, such as soda, potassa, lime, phosphorus, sulphur, and iron, in very small quantities, in the elements of nutrition.

271. What are the two kinds of food? What is the relation of the elements of nutrition to the living tissues? What is their composition? How are they characterized? What are examples of this kind of food? What do the elements of nutrition accomplish in the system?

The living tissues are built up from these elements, and by the decomposition of these tissues and their elimination, the forces of the system and animal heat are developed.

272. If the amount of heat required were in all cases exactly proportioned to the vital force required, and if the oxygen present were no more than sufficient to combine with the tissues for the production of this force, there would be no occasion for any other kinds of food. This, however, is by no means the case. A part of the year we are surrounded by a temperature little inferior to that of the body. But little animal heat is lost, and the supply required is very small, though the amount of vital force required be considerable. In the winter season the radiation of heat from the body is very rapid; and, in order to sustain the requisite temperature, heat must be rapidly developed by the system, even though but little vital force is needed. Moreover, if there were an excess of oxygen in the circulation, it would probably continue to combine with the living tissue, and produce emaciation and disease.

Hence the necessity of food which has a composition so different from living tissues that it cannot become a part of them. Of this description are the oils, the fat of animals, sugar, starch, and all of the saccharine and farinaceous parts of the grains, roots, grasses, and whatever vegetable substances are ever used as food. They are

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272. Under what circumstances may we suppose no other kinds of food would be necessary? What are the circumstances which render another kind of food necessary? What are instances of this second kind? What is their composition? What are they called? How are they eliminated from the system?

composed of oxygen, hydrogen, and carbon, but contain no nitrogen, and are called **the elements of respiration.** The oxygen and enough of the hydrogen to constitute water, will not affect the temperature of the body. The excess of the hydrogen and the whole of the carbon may combine with the oxygen of the inspired air. This combination must develop heat in proportion to the amount consumed. The products, after combination, are only carbonic acid and water, both of which are given off in large quantity by the lungs.

273. It follows, in the first place, from the different purposes to which the elements of nutrition and those of respiration are subservient, that all persons, and in all circumstances, require some food which contains the elements of nutrition, and that persons of sedentary habits need less of these elements than those whose occupations require the exertion of more physical force.

Secondly. The kind and amount of food should vary with the season and the climate. The inhabitants of warm climates eat less than those of cold, both because they need to develop less animal heat, and because they put forth less physical effort. Every person needs more of the elements of respiration in his food in winter than in summer. In the extreme northern regions, the inhabitants consume large quantities of fat, oil, and other substances which contain no nitrogen, but which are rich in carbon.[77]

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[77] With persons who indulge in free living, and who exercise but little, the oxygen received into the system is insufficient to consume entirely the carbon which belongs to the tissues, offered for decomposition. These tissues are decomposed, but the residuum is a nitrogen compound contain-

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273. Why do all persons need the elements of nutrition? Do sedentary or active persons need the most, and why? From what sources, animal or vegetable, are these to be obtained? What effect should the seasons have in the selection of food? Why is less food needed in warm climates? What is the character of the food among the inhabitants of the polar regions, and why?

If there is an excess of these elements of respiration in the system, it is deposited in the form of fat.[78]

CHAPTER IV.—OF ABSORPTION.

274. **The lacteals** are a part of the absorbent system, designed for the absorption of the chyle from the small intestine, and have been described in connection with the subject of digestion.

275. **The veins** are also absorbents. Most of the absorption of the system is undoubtedly performed by them; for the sixty gallons of blood which they return to the heart every hour is sufficiently charged with absorbed matter to change sensibly its properties. It is one special function of the veins to absorb from the stomach the nitrogenized elements of the food. Another office of the veins, as absorbents, is to take up the waste products occasioned by the decomposition of the living tissues.

276. There is a third class of absorbents, called **lymphatic vessels.** (Figs. 109, 110, 111.) They commence by a network of exceedingly minute tubes in all parts of the

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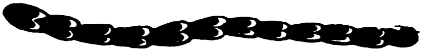
ing an excess of carbon, and in consequence becomes insoluble. It often accumulates in the bladder as stone or gravel, and can be removed only by surgical operations.

[78] Advantage is taken of this in the fattening of domestic animals. They are furnished with an abundance of such food as is readily transformed into fat: that is, of the elements of respiration. To secure these elements from being removed by respiration, every precaution is taken to diminish the quantity of oxygen received into the system, by preventing exercise, and by guarding them against exposure to a low temperature.

Chapter IV.—274. What is the office of the lacteals?
275. What is the office of the veins, as absorbents?
276. What is the third class of absorbents? Describe them.

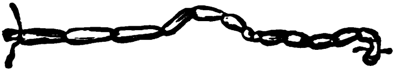
Fig. 109.



A Lymphatic Vessel, magnified.

surface of the true skin, and of all the free surfaces, such as the membranes which invest the brain, and the serous

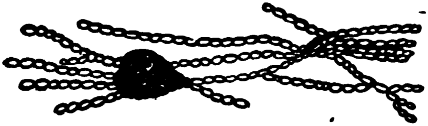
Fig. 110.



A Lymphatic Vessel laid open to show the valves.

membranes generally, the mucous and synovial membranes, the surface of the eye, and the interior surface of the arteries

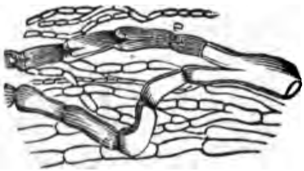
Fig. 111.



Lymphatic Vessels passing through glands.

and veins. The network of these is so close (Fig. 112) that when injected, the surface looks like a pellicle of quicksilver. As they leave the surfaces in which they originate, they are still slender tubes, but abundantly supplied with valves, occasionally passing through glands, and, though not uniting into large tubes like the veins, they converge toward the centre of the system, and finally unite in the thoracic duct. (Fig. 113.)

Fig. 112.



A Plexus of Lymphatic Vessels in the skin, magnified.

277. In all parts of the body there are substances which have performed the offices for which they were intended, and, being no longer useful, require removal. Of this nature are the secretions within the joints, thorax, abdomen, and cranium. In like manner, particles of the body, either from its ordinary motions or from accident, as in case of bruises, extravasation of blood, etc., are continually losing their vitality, and need to be removed. The removal of such substances seems to be specially the duty of the lymphatic vessels.

278. These vessels are found to contain a liquid generally colorless and somewhat resembling the serum of the blood. It is mingled with the chyle in the thoracic duct, by which this mixed fluid is conveyed into the blood. Thus every substance which has once been used, as the synovia or any of the lubricating fluids, but which is capable of being appropriated again, is returned to the circulation for that purpose. Whatever is incapable of such use will be separated from the blood by some secreting process.

279. Several conditions of the body depend on the activity or inactivity of this system.

When the absorbents of the head, thorax, abdomen, pericardium, or joints fail to absorb the fluids secreted into their cavities, dropsy occurs in those parts.

When the quantity of refuse matter in any part of the body is greater than the absorbents can remove, a tumor is formed, which increases in size till it opens a passage to the surface and the vitiated matter is discharged.

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277. What substances are they intended to absorb?

278. Describe the fluid which they convey. **What is the object of returning it into the blood?**

279. What is the effect when the absorbents of the closed cavities become inactive? What is the result when the refuse matter becomes considerable? What are eruptive diseases?

Eruptive diseases consist in the deposition of such matter near the surface of the body as the absorbents will not act upon.

280. These vessels, though they do not reach through the cuticle, are yet capable of taking up substances which exist on the surface and conveying them into the blood. Unguents, poisons, and contagious miasma, as well as moisture and liquid nutriment, are sometimes in this way conveyed into the circulation. Refuse and unwholesome matter is constantly thrown from the system by perspiration, and, if not removed by frequent ablutions, will be reabsorbed and tend to generate disease.

CHAPTER V.—OF SECRETION.

281. The secretions of the system have several objects. There is one kind of secretion the object of which is to lay up in store substances which the system may afterward need. The adipose matter, the fat of the system, is such a substance. It comes from the elements of respiration. When there is a residuum not needed at the time it is furnished, it is deposited in the cells of the loose cellular tissue, for the purpose of being removed whenever the condition of the system is such as to need a larger supply of animal heat than the daily supply of food will produce. It is this store of fat which enables hybernating animals to sustain a feeble respiration during the whole winter without taking food at all.

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280. What substances are absorbed by these vessels from the surface?

Chapter V.—281. What is the object of the secretion of fat? What is the second kind secretion? The third? The fourth?

A second class of secretions is designed to accomplish particular objects in the system. When these are accomplished, the secretion is again returned to the circulation. Such are the secretions from the serous and some of the mucous membranes.

A third class of secretions are also designed to accomplish special purposes in the system, but having accomplished these purposes, are of no further use. Such are the tears, the ear-wax, and the perspiration.

A fourth kind, of which the urine is perhaps the only example, has no other known object except the separation of refuse matter from the blood, and the rejection of it from the system.

282. The **nature of the secreting process** is not understood. It has, by some, been regarded as a chemical process, by others as a mere filtering process. But the facts are inexplicable on either theory. We may consider it as a separation of substances from the system, so controlled by the vital force as to make the selection always the one required, just as the proper selection is made of the materials for the growth and repair of the several parts of the body.[79]

283. The organs of secretion are of two kinds—surfaces and glands. Secretion takes place from all the **surfaces** of the body.

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[79] An explanation of this process on physical principles would seem to be impossible; it obviously involves something more than mere physical agency. There is choice, a function of mind, the work of a thinking Being; and yet our thinking powers have no control over it. This Being, our Divine Protector, exercises this choice for us without cessation, and in all parts of the body. Otherwise our life must cease at once.

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282. What is the nature of the secreting process?

283. How many kinds of secreting organs are there? How are the closed cavities lubricated? What is the secretion from the several parts of the alimentary canal? What is the secretion from the lungs?

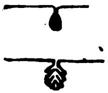
The lining membranes of all the closed cavities, such as the joints, thorax, abdomen, cranium, and pericardium, secrete fluids to lubricate them.

The membranes which line the nasal cavities, the mouth, pharynx, and esophagus, and the intestines, secrete a mucous substance for the lubrication and protection of these organs. The internal surface of the stomach is a mucous surface, but the object of its secretion is particularly the digestion of food.

The internal surface of the lungs secretes carbonic acid and watery vapor. Perhaps this ought to be regarded rather as transmission of these gases, for the surfaces seem to have no more agency in the process than lifeless membrane.

284. **The skin** furnishes two kinds of secretion, one from follicles and one from perspiratory tubes. The **follicles** (Fig. 114) are small cavities situated in the substance of the true skin, and opening at the surface by narrow orifices. They are found in all parts of the surface, but are most abundant in the arm-pits, the groins, and on the face and nose. They furnish an unctuous secretion, which serves to soften the cuticle, and probably to prevent it from being affected by the dryness or moisture of the atmosphere.[80] They are large on the edges of the eyelids, and the oily secretion probably prevents the lachrymal fluid from escaping externally.[81] They are also abundant in the ear, and produce the ear-wax.

Fig. 114.



Simple and Compound Follicles, magnified.

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[80] The orifices of the follicles are apt to become closed, and the secretion within the enlarged opening becomes hardened, producing a black speck; the contents of the follicle can be removed by pressure. These substances, from their form and hardness, have been called "worms."

[81] The inflammation of these follicles constitutes the "sty."

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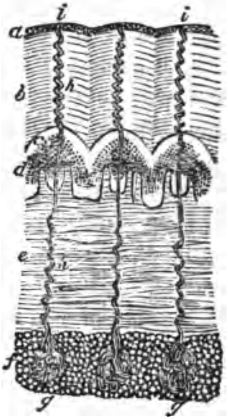
284. Describe the follicles and their secretions, and their use.

Follicles are also found in the mucous surfaces; but the secretions from them are like the secretions from the surfaces in which they are situated.

285. The most important action of the skin is that of **perspiration.** This function is performed by small tubes, which commence below the true skin in the perspiratory glands (*g, g,* Fig. 115). These tubes pass by a spiral course through the true skin and cuticle to the surface. The orifices of these tubes are, in popular language, the pores of the skin. They are very numerous, amounting in some parts of the surface to several thousands upon a square inch.

Fig. 115.



Section of the Skin of the Finger, magnified fourteen times its thickness. *g, g* The perspiratory glands, situated in the cellular tissue, *f*, below the skin. *h, h* The perspiratory tubes, passing through the several layers of the skin, and opening upon the surface, *i, i*.

286. One office of these tubes is to remove a certain amount of refuse substance from the system. It is generally in the form of insensible perspiration, that is, of vapor, which is continually escaping from all parts of the surface; but in warm weather, or during severe exercise, it is abundant enough to appear as moisture on the skin, and sometimes in drops. The perspiration consists of water slightly charged with saline ingredients. The amount of daily perspiration must be exceedingly variable; but it is probably about one-fourth of the weight of the solid and liquid substances which we take into the stomach.

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285. Describe the perspiratory apparatus.

286. What is their office? How does the perspiration appear? How much is eliminated in this way?

287. Another important office of perspiration is its influence upon the temperature of the system. We have seen that heat is produced by the combustion of the carbon of the decomposed tissues, and that provision is made for increasing it by furnishing certain kinds of food which have no other object. But we often need the means of also reducing the heat. We may often be surrounded by a temperature equal, or nearly equal, to that of the system. Heat will continue to be generated, but there will be none radiated. It is the office of perspiration to effect its removal. Water, at the temperature of the body, must absorb eleven hundred degrees of heat in order to become vapor. For every ounce, therefore, of water given off in a state of vapor by perspiration, enough heat has been taken from the system to heat seventy pounds of water one degree. The apparatus of perspiration has thence the power of abstracting heat with great rapidity; and as the temperature rises, the rapidity of perspiration increases. So complete is this protection, that a person may remain for half an hour in an oven sufficiently heated to cook his dinner and not be injured, provided his perspiratory system be in a state of great activity.[82]

288. The follicular secretions are not of a nature to be

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[82] It is scarcely credible that the human system can endure a temperature so high as, in perfectly well authenticated cases, it is known to have endured. Sir Charles Blagden and others exposed themselves to a temperature of 260°, that is, about 50° above the temperature of boiling water, without injury. Chantrey, the sculptor, often entered his drying-rooms when they were at a temperature of more than 300°. It has been said that ovens heated to a temperature of 600° have been entered by some of the famous fire-kings, without injury; but the accuracy of these statements may be doubted.

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287. What other office has perspiration? Why is this necessary? How does it accomplish this object?

288. Why is frequent ablution necessary? By what should we be governed evaporated, and the saline ingredients of the perspiration are also left on the surface. In order that these substances may not obstruct the pores of the skin, and that they be not absorbed by the lymphatic vessels, it is important that the entire surface be washed daily with water and soap, or some other similar detergent. The method may be by the water bath, vapor bath, by showering or sponging, according to the convenience of each individual.

Experience must teach us whether warm or cold water should be used. If there is a healthy and vigorous reaction after using cold water, then that is to be preferred If the surface becomes shrivelled and pallid by the use of it, then warm water is better. And in all cases sufficient friction upon the surface should be produced by the towel or flesh-brush, to restore an energetic circulation.

Lastly. The clothing and exercise should always be such as to preserve the requisite warmth and keep open and active the perspiratory orifices.

289. Secretion from glands. Most of these secretions are subservient to other functions, and have already been described. The principal of these secretions are from the lachrymal and salivary glands, and from the liver and pancreas.

290. The kidneys (Fig. 116) are two large glands situated in the lower part of the abdomen, one on each side of the spine. They receive a very large supply of blood, and secrete from it the urine, which is conveyed by the ureters to the bladder, and is thence expelled from the system.

The importance of this secretion consists in the fact

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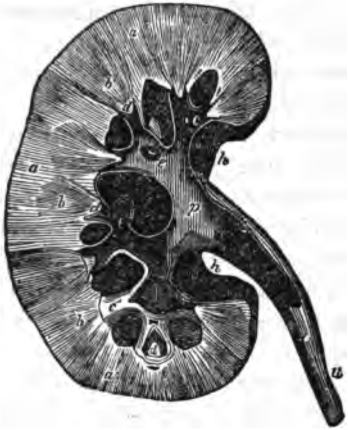
in selecting warm or cold water? What conditions besides cleanliness are necessary to the healthful action of the perspiratory system?

289. What glands have been before described?

290. Describe the kidneys. In what respect are they important?

Fig. 116.



Section of the Kidney.

that it is the only one by which certain substances can be eliminated. The urea, that is, the solid portion, which remains when urine is evaporated, is derived from the decomposition of the tissues, muscle, cartilage, etc. It is the nitrogenized compound left when the oxygen of the blood-cells has combined with most of the carbon. For the separation of this substance from the blood there is no other provision but the kidneys; and if it were not removed, the blood would very soon be incapable of carrying on the functions of nutrition.

291. In addition to the glands above named, there is the **spleen**, situated at the left of the stomach, the office of which is supposed to be to receive the blood, during the intervals between digestion, which the stomach receives while digestion is going on, and thus the constant and in-

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291. What is the situation and use of the spleen? Of the thymus and thyroid glands?

jurious accumulation of the gastric juice is prevented. There are also the **thymus** and **thyroid glands**, situated in the neck, which are subservient to infantile life, probably by receiving and returning the blood which in maturer life is sent to the brain.

292. The healthy action of the secreting organs is of the utmost importance. If the urine is not secreted, the blood is soon poisoned. When this secretion is too copious it becomes a dangerous disease. If the gastric juice is deficient, digestion ceases. Upon derangement of the biliary secretion arise some of the most formidable diseases. If the synovia is not secreted, the joints become immovable, etc.

293. It is also important to observe that there is an intimate sympathy between several of the secreting organs, especially the skin, mucous membrane of the nose, the intestines, the lungs, and the kidneys. If the action of one is interfered with, its office is assumed by another. Thus in cold weather, and especially if a person is not sufficiently protected during sleep, the pores of the skin become contracted and inactive, and the urinary secretion is increased. But the sudden contraction of these pores by a draft of air checks the perspiration, and determines either an increased action of the mucous membrane of the nose, when we have a cold in the head, or the extra labor is thrown upon the respiratory organs, and we have a cold upon the lungs, or the mucous membrane of the intestines becomes active to excess, and results in diarrhœa dysentery.

When the surface of the lungs becomes diseased, or bronchial tubes become obstructed so that less oxygen is

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292. Illustrate the importance of the healthy action of the secreting organs.

293. Give instances of the sympathy existing between the secreting organs. How should this transfer of functions be regarded ?

taken up by the lungs, the amount of carbon consumed in the system is too small, and an excess is therefore contained in the residuum which it is the office of the kidneys to remove. But with an excess of carbon this residuum is but slightly soluble. Hence, the urine secreted when there is a cold upon the lungs is highly colored, and upon cooling deposits a thick sediment. This insoluble substance may be secreted so rapidly that it collects in a solid form in the bladder.

This transfer of functions is a condition of disease; but it is the effort of nature to relieve us from still greater danger. The diseased action of the lungs, nasal cavities, or intestines is less injurious than it would be to have in the system the substance which should have been excreted by the skin. It would, therefore, be unwise to attempt to check this disease directly. Allow it to continue to perform, in place of the skin, a service which is necessary to the general health of the system, and remove the disease only by re-establishing that function which has been suspended.

CHAPTER VI.—HYGIENE.

294. Most of the principles and rules in regard to the preservation of health have already been stated in connection with the general subjects from which they arise, but it has been thought best to bring them into a more compact form. It may, then, be stated that the body is a mechanism, and, as such, must, with use, wear out. Such statement has been objected to on the ground of the perfectness of the repairing system; but it may well be

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Chapter VI.—294. Why is the body subject to wear? Are repairs ever doubted whether repairs are ever *perfect.* Certain it is that all severe injuries, even when cured, are in a less perfect state than the same part was before the injury occurred. A wound never so heals as to leave no scar. A broken bone adheres completely, but rheumatism will select the place of fracture in preference to any other; so that death really begins as soon as we begin to live. Yet it is not improbable that the threescore years and ten might always be attained if no accidents were to intervene and if the laws of health were never violated.

It is the business of hygiene to state, as far as they are known, what these laws of health are. It is not, however, to be inferred that we should never be sick if we observed exactly these laws. It is probable that many diseases have been inherited; that is, diseases have been induced by infraction of hygienic laws on the part of those from whom we have descended, and these diseases have become so ingrafted into our systems that our natures are really *tainted.* Those singular diseases of which we can have but one attack, like whooping-cough, are probably the result of some poison fixed in the system by habits of diet or of life not at the time known to be hurtful. We know not how much of the seeds of disease we inherit, tending in some instances to specific disease, sometimes only to less perfect general constitution.

Still this deterioration has not gone so far but that a proper observance of hygienic rules will dispose us to a healthy state, and in most cases secure us against disease. Our ailments are always aggravated by indiscretions, and in a large proportion of cases produced by them.

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perfect? What is the object of hygiene? Why does not the observance of hygienic rules invariably secure us against disease? Can disease be inherited? Are hygienic rules still useful? How can we affect our health? Does hygiene propose to cure disease?

We can affect our health principally through the repairing system. Hence the rules of health must be based on the nature and use of this system. The means to be employed may be either external or internal, but they are not curative means. These the physician only should use when disease has been induced. It is the office of hygiene to teach us how to use these organs so as to prevent the occurrence of disease.

295. *Cleanliness.*—Most of the pursuits of life soil the hands and even the face, and frequent washing is necessary as a question of decency; but general washing of the body becomes necessary also as a question of health. The perspiratory tubes and follicles discharge probably half of the excreted matter of the system. It is mostly water, but there is some saline ingredient and some oleaginous, both of which, as they do not evaporate, remain on the surface. Besides, the extreme outer portion of the cuticle is always separating in the form of minute flakes, which, however, continue to adhere to the cuticle. All these substances tend to choke up the excretory openings, and prevent them from effecting that relief to the system for which they were intended.

It is obvious, then, that frequent, perhaps daily, ablutions are necessary. Bathing should be resorted to if possible, but the shower-bath or washing may be substituted, always with the use of soap—soap and civilization are inseparable. After the use of water, the surface should be rapidly dried with a towel, and friction enough applied with a flesh-brush or coarse towel to establish a vigorous surface circulation and a general feeling of warmth and comfort.

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295. What is the first law of health? Why is washing necessary? What should follow washing or bathing?

296. *Exercise.*—In a large proportion of the forms of human pursuit there is bodily activity enough for maintaining the health of the several organs. But some of these forms, while they are useful and even laborious, give exercise to only a small proportion of the organs. Thus the seamstress uses only the hands, the student only the brain, the accountant only the brain and hand. It becomes necessary that some kinds of exercise be resorted to which have no other real object than the exercise itself. If, however, some other interest can be connected with it, as ball, boating, riding on horseback, or gymnastic feats, still salutary exercise is secured. Some less exciting occupation, as walking or hand-labor, will, however, if entered upon with a cheerful mind, be of equal service.

It should, however, be borne in mind by all persons who follow sedentary pursuits that active exercise is essential to the maintenance of the constitution unimpaired. Physical activity is a necessary condition of physical health. Such activity induces a greater amount of respiration, more action of all of the muscles of the chest and abdomen. The action of the heart is increased, and thus the circulation is augmented. With this increased respiration and circulation all of the powers are stimulated, digestion is promoted, muscular strength is increased, and mental activity is encouraged. The exercise should, then, be continued till this energetic circulation is established, generally till sensible perspiration begins to appear.

297. *Dress.*—The inferior animals are furnished, either by their instincts or by special variations of clothing according to the season, with protection against injury from

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296. What is the second condition of health? Why is exercise beyond ordinary labor necessary? What kind of exercise is required? What is the effect of exercise? How long should it be continued?

297. What is the object of clothing? Upon what does the warmth of clothing variations of temperature. In our species this protection is left to our reason. The object of clothing is, in winter to prevent the escape of the heat which the system furnishes, and in summer to favor its escape. The warmth of clothing depends on the non-conducting power which it possesses, either from its own nature or from the stratum of non-conducting air which, by its porous structure, it imprisons. The coolness of clothing depends on the rapidity with which it conducts away the heat which the system furnishes. Hence woollen fabrics are the best for winter clothing, as they are at all seasons for persons who, like operatives in a rolling-mill, need to shut out the excessive heat by which they are surrounded; and linen or cotton fabrics furnish the cooler varieties of clothing.

The lighter the clothing, consistent with the requisite warmth, the better.

All parts of the body require this protection, and hence the habit of dressing, and especially of dressing children, so as to expose the arms and neck is objectionable.

The adjustment of dress is as important as the material. The first condition of dress is protection, but this protection should not be at the expense of any other requisite of health. Especially the clothes should not be permitted to restrict the free action of the lungs. The compression of the chest is one of the extreme evils in the modes of female dress, and men are not wholly exempt from blame in this respect. Similar objection rests against the retaining of clothes of men or women in place around the waist, without suspending them from the shoulders; also the close-fitting ribbon, or necktie, or cravat around the neck;

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depend? When is woollen clothing required? When linen or cotton clothing? What amount of clothing is necessary? What parts may be without clothing? What other condition besides warmth of clothing is necessary? What injurious effects result from wrong methods of adjusting the clothing?

and that person will be a benefactor who can devise a means of keeping stockings in their place without the use of garters or elastics so close-fitting as to impede the circulation.

298. *Air.*—The air contains about one-fifth of its volume of oxygen. The rest is nitrogen, except a very small proportion of carbonic acid and some watery vapor. In this condition it is the proper support of respiration.

But it is liable to great deterioration. An injurious amount of carbonic acid is likely to accumulate by the process of respiration, which converts about one-fourth of the respired oxygen into carbonic acid. The combustion of gas, oil, or tallow in producing artificial light, must furnish a large amount of carbonic acid, enough to have a perceptible influence on the purity of air in the rooms which we occupy in the evenings. Large rooms, with high walls and abundant ventilation, are the only protection against injuries from this cause.

Several other forms of impurity often occur. Among these are the dust arising from various kinds of manufacture, poison from linseed oil and paints, and especially the excessive accumulations of watery vapor near masses of water where the air is confined by the walls of cellars and buildings, in narrow alleys, or in deep valleys shut out from the action of winds.

But the greatest danger arises from poisonous miasma, often in quantity too small to be detected by chemical tests, but in sufficient quantity to breed disease. One of the principal sources of this poison is decaying animal and vegetable matter. The remains of winter vegetables left in a cellar will generate it. Stagnant marshes in which

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298. What is the composition of the air? What is the first source of deterioration mentioned? How does the artificial light of rooms affect the air? What are some of the common sources of impurity? What is the source of the annual vegetation decays, will become covered with a green scum, and the whole region becomes offensive; and yet families will maintain a miserable existence in the immediate vicinity, with constant recurrence of chills and fever. Another and more poisonous miasma is generated in hospitals and sick-rooms. This is a necessary result of sickness, and is thrown off both from the surface and from the lungs. In many cases the poison is specific, and produces the same diseases as those have from whom it emanates, as measles; but often it has only a general depressing effect upon those who must be in attendance. The health must suffer, though active disease may or may not result.

The general remedial agencies against these forms of poison must be found in the drainage of standing water, in removing decaying matter from the vicinity of human abodes, in the free use of disinfectants, such as charcoal or chlorine, and in sick-rooms, above everything else, abundant ventilation. Perhaps the free introduction of sunlight into sick-rooms will be found of value, not only as a disinfectant, but as a remedial agent much more efficacious than has been supposed.

299. *Water* may be regarded as a portion of our food, both because it is taken in so large quantity in the liquid state, and also because it forms so large a proportion of our solid food. It is the means of adjusting the temperature of the body, of eliminating the carbonic acid from the lungs, saline and oily substances through the skin, and the nitrogenized products of waste by the kidneys.

The most important agency of water in the system depends on its great solvent power. But this property also

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greatest danger? Why are sick-rooms the source of impurity to the air? What are remedial agencies?

299. Is water food? What purposes does it accomplish? Why is water so renders it liable to be frequently contaminated. The contamination may be only slight and its effects may be only slowly cumulative, unobservable perhaps for months, and then show themselves in such forms of disease as are at once and obviously traceable to this source. Its work is imperceptibly slow, but the constitution is no less certainly undermined.

The best water, that is, water containing the least foreign matter, is rain-water. But water is never free from some foreign ingredients. Even when it has been subjected to natural distillation by being taken up into the atmosphere as vapor and condensed into clouds, and finally into rain and snow, it absorbs in its passage through the air oxygen, carbonic acid, and ammonia. These additions are not regarded as hurtful. The water of springs and streams in granitic and other silicious geological formations, has nearly equal purity with rain-water.

But the water that falls upon the surface of the earth where the formations are either alluvial or calcareous, reappears as springs in which the water is highly charged with hurtful ingredients, mostly in the form of lime or magnesia. Waters of this kind are known in common language as "hard." Where hard water abounds, the taste of those who use it so adapts itself that the water is not disagreeable, but is greatly preferred to soft water; yet it is, undoubtedly, to some extent, hurtful. It compels the system to take on an abnormal condition, and hence favors either directly the occurrence of some disease, as goitre, or it operates conjointly with other causes in inducing disease of the digestive organs.

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likely to be impure? What water is the purest? What impurities does rain-water contain? What is the character of spring-water in the regions of granite rocks? Why is the water obtained from calcareous regions impure? What is this water called? Is it wholesome? What are the most injurious ingredients?

The so-called mineral waters, containing in solution saline ingredients, sulphuretted hydrogen, etc., are used only for their medicinal qualities, and need not here be considered.

Deleterious ingredients of the more important class are of organic origin. Soils of every kind contain decaying animal and vegetable matters. Most of the springs from which wells are supplied must be fed from rain-water which has passed through such soils. The rocks through which it has filtered have deprived the water of much of its impurity, but many wells, especially those of no great depth, contain traces of impurities which the surface-soil has imparted. But no precaution can prevent impurities both in the wells and in the rivers in the vicinity of large cities, where the refuse from manufacturing establishments and the contents of cesspools and sewers must be disposed of. Hence, the obtaining of water for cities from a distance and from the purest sources is necessary to health, and all requisite expenditures, however great, are regarded as justifiable and imperative.

300. *Food.*—It must be assumed that every form of food is in a good condition. Thus, meats should be from healthy animals, and free from the taint of incipient decomposition; fruits should not be either unripe or over-ripe; vegetables should be fresh; the cooking should be to that extent most conducive to digestion; butter should be free from rancidity; bread should be porous, sweet, well baked, and not entirely new, etc.

As the object of food is to provide for the growth and supply the waste of the system, both the amount and kind

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Why is well-water likely to be impure? Why cannot the water of wells and rivers near large cities be pure? How is the evil to be remedied?

300. What are the requisites of good food, as meats, fruits, etc.? What amount of food is necessary before growth is completed? How should the amount

should be such as to meet these wants. Hence the amount, before full growth is attained, should exceed the waste. After growth is complete, the amount should vary with the occupation, increasing with the increase of our activities, in order to the continued production of force; increasing also with the exposure to low temperatures, in order to supplement the reduced amount of external heat by a larger supply of vital heat.

The kind of food should also vary with our condition. Nitrogenized food, and considerable of it in the form of animal food, is required when much force is to be expended. Respiratory food is required in cold weather; and in high latitudes or where there is great exposure, it should be in large quantity and in the most concentrated form, that is, in the form of animal fats. In a mild or warm temperature, where little effort is called for, a vegetable diet will best meet the wants of the system.

Any kind of food long persisted in, however suitable it may be in all other respects, is unfavorable to health. There must be change, diversity.

Generally correct ideas about food being established, it ought to be added that nothing is more certain to induce disease than the constant apprehension that our food may injure us. Special solicitude about the effects of food upon us will soon induce hypochondriasm, which is itself disease and the forerunner of many diseases.

Insufficiency of food is a prolific source of disease. Even though the scantiness do not approach starvation, or produce the sufferings of real hunger, if the supply fall below the actual waste, the powers become enfeebled, the mind

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be adjusted afterward? How should the nitrogenized food be regulated? How the respiratory food? Can a uniform diet be safely adopted? Should we be constantly anxious about the effects of our food? What effects follow from insufficiency of food? What from excess of food?

loses vigor, energy is weakened, the ambition of success subsides, the physical strength fails, and low febrile symptoms, and finally some form of typhoid disease generally follows. If the deficiency is in the vegetable ingredients of food, scurvy is apt to follow. If it be in the oleaginous portion, a scrofulous habit supervenes, and finally tubercular consumption.

Excess of food is equally injurious. When more is taken into the system than can be appropriated for its purposes, either the stomach is overtaxed and dyspepsia results, or the liver is overtaxed and bilious fevers are induced.

GENERAL QUESTIONS ON THE REPAIRING SYSTEM.

Give the analysis of the repairing system.

CHAPTER I.—Describe the peritoneum. Of what do the sections of this chapter, in their order, treat?

SECTION I.—Describe the mode of development of the teeth. How are they divided? In the case of the teeth, what are the three precautions to be observed? Describe the salivary glands. The tongue. The pharynx. The esophagus. The physiology of mastication and deglutition.

SECTION II.—Describe the stomach. Give the physiology of the stomach. Why does the digestive system require special care? What are the two objects for which food is taken? What circumstances require the most concentrated, and what the least concentrated food? What are the general principles for the selection of food in health? What in dyspeptic disease? Why are liquid substances required in the system? How are they received into the circulation? What modifications in food are effected by cooking, and how do these changes affect the system? How are we to judge of the quantity of food needed? What are the practical rules in reference to the times of taking food, and what are the grounds of them? What are the conditions favorable to digestion?

SECTION III.—Describe the duodenum. The liver. The pancreas. Give the physiology of these organs.

SECTION IV.—Describe the small intestine. The mesentery. Give the physiology of the small intestine. Describe the large intestine.

CHAPTER II.—Describe the blood. The pericardium. The heart. Its valves. The arteries. Their valves. The distribution of the arteries. The veins. The course of the circulation. The forces by which it is sustained. The amount of daily circulation. How is the pulse produced? What rules are to be observed when an artery is wounded? For what purpose is the anastomosing of the arteries? How may we estimate the amount of nutrition performed? Where does nutrition take place? Describe the capillaries and their use.

CHAPTER III.—Describe the pleura. The larynx. How is the voice produced? Describe the trachea. The lungs. How is respiration produced? What is the ordinary amount of respiration? What circumstances affect the amount? What proportion is oxygen? What circumstances may vary the amount of oxygen received? From what sources is carbonic acid derived? How is it injurious? Why should rooms intended for a large number of persons be well ventilated? How is the oxygen received into the blood? How much is received in comparison with the amount of blood circulated? What changes are effected in the blood by respiration? In what way are these changes made? What is the vital force? How does it become mechanical force? Give the facts which corroborate this explanation. What is the second object of respiration? How is the heat produced? What are the two kinds of food? What is the composition of each? Give examples of each. What is the object of each in the system? Under what circumstances should each kind be used?

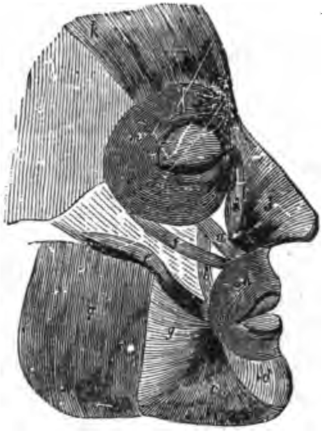
CHAPTER IV.—For what are the lacteals designed? How is it shown that the veins act as absorbents? Describe the third class of absorbents. Their office. What conditions of the system depend upon their activity?

CHAPTER V.—What are the four classes of secretions? Describe the secreting process. What are the organs of secretion? What secretions are performed by surfaces? Describe the follicles and their physiology. The perspiratory apparatus. What is its physiology as an excretory system, as connected with the temperature of the body? What are the principal glands? Describe the kidneys and their use. The spleen and thymus and thyroid glands. The relation existing between the secreting organs.

APPENDIX.

THE following description of the individual muscles has been, without changing the paging or the numbers of the paragraphs, transferred to this position in the book instead of following the section on the muscles generally, because, while it is too technical to be required of classes in recitation, it is believed that many will feel sufficient interest in the subject to give it examination.

Fig. 56.



Muscles of the Face. *a* The levator labii superioris. *b* The levator anguli oris. *c* The depressor anguli oris. *d* The depressor labii inferioris. *e* The zygomaticus major. *g* The buccinator. *h* The orbicularis oris. *i* The levator alæ nasi. *j* The compressor naris. *k l* The occipito-frontalis. *m* The orbicularis oculi. *q* The masseter muscle.

SECTION II.—The Muscles individually.

80. I.—*Muscles of the forehead.*

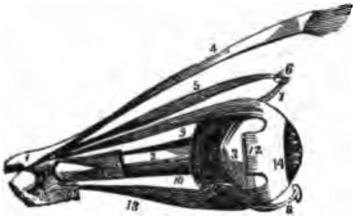
(*a*) The **occipito-frontalis** (*k*, *l*, Fig. 56) arises from the ridge of the occipital bone, extends forward so as to cover the top of the cranium, and is inserted into the skin at the lower part of the forehead. It raises the eyebrows and wrinkles the forehead horizontally.

(*b*) The **corrugator supercilii** (not represented in the figure) arises from the frontal bone near the inner angle of the eye, runs upward and outward, and is inserted into the skin under the eyebrow. It antagonizes with the frontalis, and wrinkles the forehead vertically.

81. II.—*Muscles of the eye.*

(*a*) The straight muscles, namely, the **rectus superior** (9, Fig. 57), the **rectus inferior** (13), the **rectus internus** (10), and the **rectus externus** (11, 12, most of it is represented as removed in order to show other parts). These four muscles arise in the posterior part of the orbit, and extend forward to be inserted into the eyeball, one above, one below, and one on each side. Acting separately, they roll the eye in different directions; acting together, they depress the ball in the socket.

Fig. 57.



Muscles of the Eye. 2 The optic nerve. 3 The eye-ball. 4 The levator muscle of the eyelid. 5 The superior oblique muscle. 6 The loop through which its tendon passes. 7 The tendon which is inserted into the ball. 8 The inferior oblique muscle. 9 The rectus superior. 10 The rectus internus. 11, 12 Portions of the rectus externus. 13 The rectus inferior.

(*b*) The oblique muscles. The **obliquus superior** (5) has a common origin with the recti muscles. It runs obliquely over the eye to the inner angle, where its tendon passes through a cartilaginous ring (6), and is reflected back to be inserted into the ball (near 3). The **obliquus inferior** (8) arises near the inner angle of the eye, runs obliquely backward under the eye, and is inserted into the posterior part of the ball. The oblique muscles, acting separately, roll the eye in opposite directions; acting together, they antagonize with the recti muscles, and bring the ball forward.

(*c*) The **levator palpebræ superioris** (4) has a common origin with the recti muscles, and is inserted into the cartilage which forms the upper eyelid.

(*d*) The **orbicularis oculi** (*m*, Fig. 56) is a circular muscle surrounding the eye. It has its origin and insertion common at the inner angle, and its use is to close the eye.

82. III.—*Muscles of the nose.*

(*a*) The **compressor naris** (*j*, Fig. 56) arises from the corner of the nose, spreads over the ridge of the nose, and its fibres mingle with those of the corresponding muscle from the other side. Its action is to diminish the size of the nostrils.

(*b*) The **levator alæ nasi** (*i*, Fig. 56) arises from the nasal process of the superior maxillary bone, and is inserted into the corner of the nose. It enlarges the nostrils.

83. IV. *Muscles of the mouth.*

(*a*) The **levator labii superioris** (*a*) has its origin directly below the eye, and is inserted into the middle of the upper lip. It raises the lip.

(*b*) The **depressor labii superioris** is a short muscle within the mouth which arises near the root of the upper canine tooth, and is inserted into the upper lip just below the nose.

(*c*) The **levator anguli oris** (*b*) arises just below the eye, and is inserted into the corner of the mouth, which it is designed to raise.

(*d*) The **depressor anguli oris** (*c*) arises from the lower edge of the lower jaw bone, and is inserted into the corner of the mouth, which it depresses.

(*e*) The **levator labii inferioris** arises near the roots of the lower incisor teeth, passes downward, and is inserted into the integuments of the chin. It raises the lower lip.

(*f*) The **depressor labii inferioris** (*d*) arises from the lower edge of the lower jaw on the side of the chin, and is inserted into the lower lip, which it depresses.

(*g*) The **buccinator** (*g*) arises from several points near the joint of the lower jaw, constitutes the principal part of the cheek, and comes forward to be inserted into the corner of the mouth. It diminishes the cavity of the mouth, or draws back the angle of the mouth.

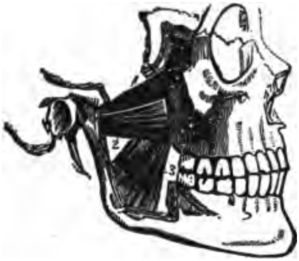
(*h*) The **orbicularis oris** (*h*) is a broad, circular muscle encompassing the mouth. It antagonizes with all the muscles that tend to open it.

84. V.—*Muscles which move the lower jaw.*

(*a*) The **temporal** muscle (4, Fig. 9) arises from the parietal bone, and the fasciculi converge till it becomes tendonous and passes under the zygomatic process, and is inserted into the coronoid process (5). It raises the lower jaw.

(*b*) The **masseter** muscle (*q*, Fig. 56) arises from the malar portion of the zygomatic process, from the malar bone, and from the contiguous portion of the upper maxillary. One portion has its fibres so situated, that, being inserted into the root of the coronoid process, by contraction it carries the lower jaw backward. The other and principal portion is inserted into the angle of the jaw. It tends slightly to bring the jaw forward, but its principal use is to assist the temporal muscle in mastication.

Fig. 58.



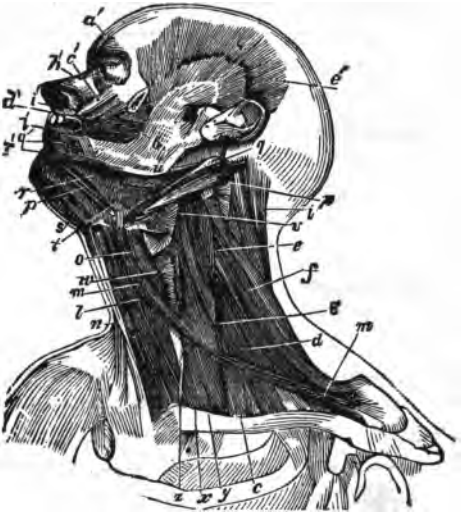
The two Pterygoid Muscles. Parts of the upper and lower jaws are removed to exhibit them. 1, 2 The external and 3 the internal pterygoid muscles.

(*c*) The pterygoid muscles (of which 1, 2, Fig. 58, is the exterior and 3 is the interior) arise from each pterygoid process, and are inserted into the inner surface of the angle of the jaw. They act alternately, and therefore produce the horizontal, grinding motion of the jaw.

85. VI.—*Muscles of the throat.*

(*a*) The **sterno-hyoideus** (*l*, Fig. 59) arises from the top of the sternum, and is inserted into the os hyoides. It draws the hyoides downward and forward.

Fig. 59.



Muscles of the Neck.

(*b*) The **omo-hyoideus** (*m m*) arises from the upper edge of the scapula near the outer angle, and is inserted into the os hyoides. It draws the hyoides downward and backward.

(*c*) The **mylo-hyoideus** arises from the lower edge of the lower maxillary bone, and is inserted into the os hyoides. It forms the floor of the mouth, and the body of the tongue rests upon it. It brings the hyoides upward and forward.

(*d*) The **stylo-hyoideus** (*q*) arises from the styloid process, and is inserted into the os hyoides. It draws the hyoides upward and backward.

(*e*) The **digastricus** (*p p*) arises from the mastoid process, passes downward and forward through a perforation in the stylo-hyoideus to the os hyoides, to which it is attached, then changing its direction, it goes to be inserted into the point of the chin. It lifts the os hyoides, and with it the tongue and throat. But when the sterno-hyoideus and the omo-hyoideus are in a state of contraction so that the hyoid bone cannot rise, then the mylo-hyoideus and the digastricus will draw the lower jaw downward.

86. VII.—*Muscles of the neck.*

(*a*) The **sterno-cleido-mastoideus** (the prominent oblique muscle on each side of the neck) arises from the sternum and clavicle, goes obliquely upward and backward, and is inserted into the mastoid process. When one muscle alone acts it brings the head obliquely forward. When they act on both sides at the same time, the head is brought directly forward.

(*b*) The **splenius** arises from the spinous and transverse processes of the vertebral column as far down as the fifth dorsal vertebra, and, as it ascends along the back, goes obliquely to be inserted just back of the mastoid process. (2, pl. I.)

(*c*) The **complexus** has nearly the same origin and course, but has its insertion into the occipital bone directly behind the insertion of the splenius. (1, pl. I.) When the splenius and complexus act on both sides they move the head directly backward. When only those on one side act they turn the head obliquely backward. These two muscles are the antagonists of the mastoideus. When all these muscles act together by a moderate force, they tend to keep the head in an erect position.

(*d*) The **obliquus capitis inferior** arises from the spinous process of the second cervical vertebra, and is inserted into the transverse process of the first. It, therefore, turns the first vertebra horizontally on the pivot joint, between it and the second, and the head partakes of the same horizontal motion. If, however, both muscles act together, they tend to steady the head in its position.

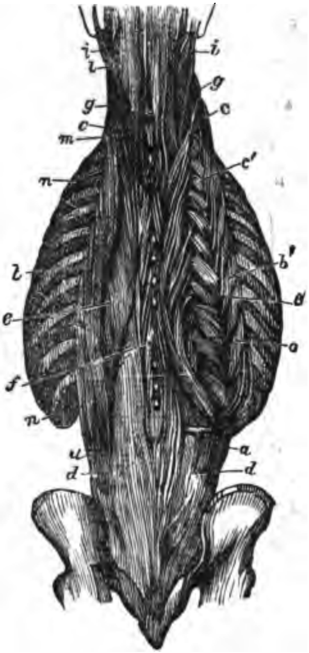
87. VIII. — *Muscles which move the spine.*

(*a*) The **longissimus dorsi** (*d e*, Fig. 60) arises from the spinous processes of the sacrum and the lumbar vertebræ, and from the contiguous portions of the ilium, passes up along the spine, filling the space between the spinous and transverse processes, and is inserted into the transverse processes of all the dorsal vertebræ except the lowest. Its use is to keep the spine erect. It also helps to bend it backward, or obliquely backward.

(*b*) The **sacro lumbalis** (*a b*) has nearly the same origin as the longissimus, and is inserted into the ribs a little forward of each tubercle. Its use is the same as that of the longissimus.

(*c*) The **quadratus lum-**

Fig. 60.



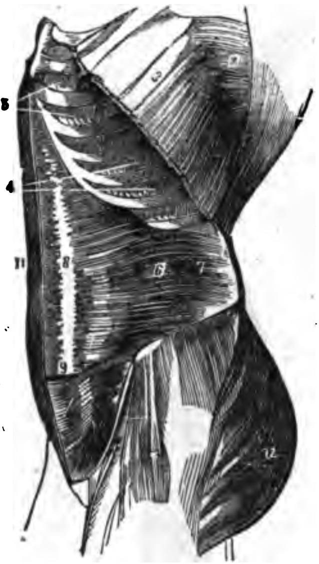
d e **The longissimus dorsi.** ***a b*** **The sacro lumbalis.** ***c o*** **The levatores costarum.**

borum arises from the highest portions of the rim of the pelvis, and is inserted into the transverse process of the last dorsal vertebra, and into the lower edge of the lowest rib. It keeps the trunk erect, or bends it to either side.

88. IX.—*Muscles of respiration.*

(*a*) The **serratus posticus superior** arises from the spinous processes of the three lower cervical vertebræ, and is inserted into the second, third, and fourth ribs on the front side of the thorax. Its direct use is to raise these ribs, but from the manner in which the ribs are connected it tends to raise all of the ribs.

Fig. 61.



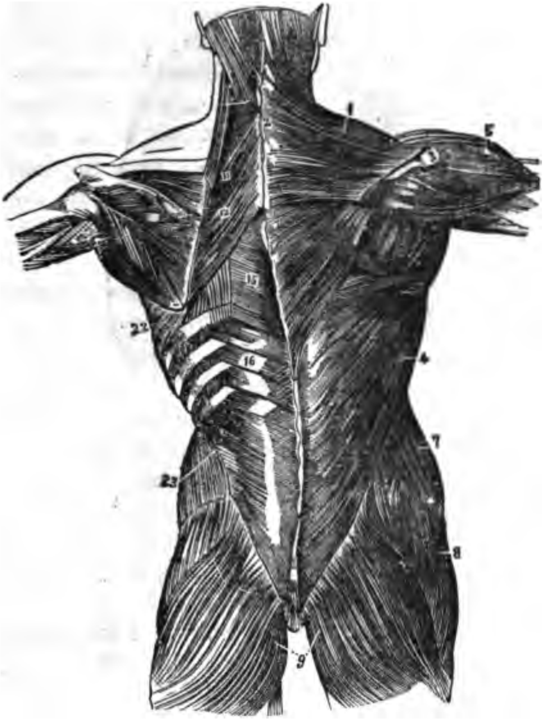
4 External intercostal muscles. 5 Internal intercostal muscles. 6 The transversalis muscle. 8 The linea alba. 11 The rectus abdominis.

(*b*) The **levatores costarum** (*c o*, Fig. 60), twelve in number, arise one from the transverse process of the last cervical and each of the dorsal vertebræ except the last, and passing obliquely downward is inserted into the rib immediately below. They assist the serratus posticus superior.

(*c*) The **intercostales** (4 and 5, Fig. 61) are short muscles filling the spaces between the ribs. The internal layer passes upward and forward. The external layer runs obliquely upward and backward. When the upper rib becomes fixed by the action of the muscles above it, the intercostales raise all the ribs below the first.

(*d*) The **serratus posticus inferior** (16, Fig. 62) arises from the spinous processes of the lumbar vertebræ, and rising forward, are inserted into the ends of the tenth, eleventh, and twelfth ribs. It brings the ribs downward.

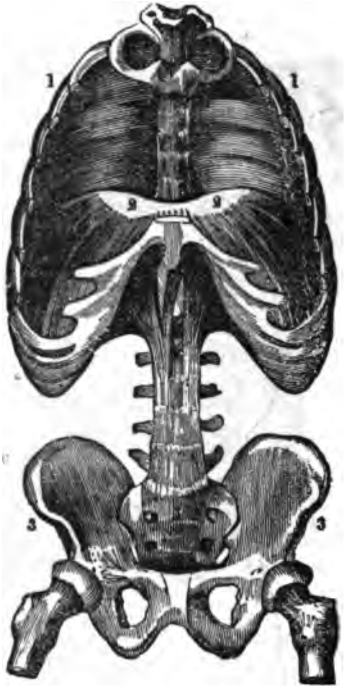
Fig. 62.



1 The trapezius. 4 The latissimus dorsi. 5 The deltoid muscle. 8 The gluteus medius. 9 The gluteus maximus. 11, 12 The rhomboideus muscle. 16 The serratus posticus inferior. 22 The serratus anticus major.

(*e*) The **diaphragm** (2, 2, Fig. 63) is a muscular membrane separating the cavity of the thorax from that of the abdomen. Its form is that of a dome, being convex above, like an inverted basin. It is seen in section in Fig. 63. It is attached to the lower extremity of the sternum and to the ends of all the ribs. Its muscular fibres have a very irregular arrangement, but the general effect of their contraction is to depress the dome more nearly to a plain surface, and of course to increase the cavity of the thorax by pressing down the viscera of the abdomen.

Fig. 63.

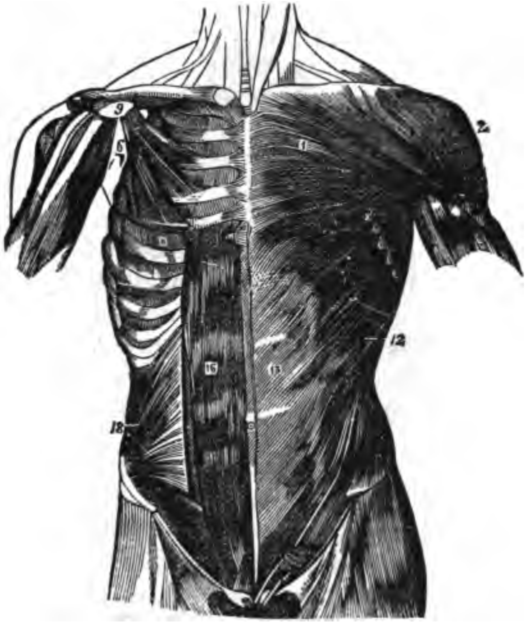


The Thorax, the front part removed to show the diaphragm, 2, 2.

89. X.—*Muscles of the abdomen.*

(*a*) The **obliquus descendens externus** (12, 13, Fig. 64) arises from the extremities of the eight inferior ribs, and proceeds obliquely downward to the **linea alba** (which is a tendonous substance occupying the median line of the abdomen, from the sternum to the pelvis, and seen at 8, 9, Fig. 61).

Fig. 64.



Front view of the Muscles of the Trunk. 1 The pectoralis major. 2 The deltoid muscle. 12, 13 The external oblique muscle. 16 The rectus abdominis. 18 The internal oblique muscle.

(*b*) The **obliquus ascendens internus** (18, Fig. 64) arises from the brim of the pelvis, and is inserted into the linea alba, sternum, and false ribs.

(*c*) The **transversalis abdominis** (6, 7, Fig. 61) arises from the lumbar vertebræ and the ends of the false ribs, and passes horizontally around the abdomen to be inserted into the linea aspera.

(*d*) The **rectus abdominis** (16, Fig. 64) arises from the sternum and the cartilages immediately adjacent, and descends vertically to the pelvis.

The direct use of these muscles is to compress the abdomen. But by so doing they cause the viscera of the abdomen to ascend, and the arch of the diaphragm is raised up. As the diaphragm descends, these muscles relax to make room for the depressed viscera.[28] They are thus the muscles which antagonize with the diaphragm, and though they have other uses, they are also respiratory muscles. The first, second, and fourth also bend the body obliquely or directly forward.

99. XI.—*Muscles of the upper extremities.*

1. Muscles of the Scapula.

(*a*) The **trapezius** (1, Fig. 62) arises from the occipital bone, from a tendonous substance called the ligamentum nuchæ, which passes along the spinous processes of the neck, and from the spinous processes of all the dorsal vertebræ. It is inserted into the spine of the scapula and into the acromion process. It draws the scapula backward.

---

[28] It is in this way that exercise is essentially connected with digestion, and that a want of exercise brings on a constipated state of the intestines. Exercise always increases the demand for oxygen in the system; hence the deep, labored respiration of a person who has been exerting himself to his utmost. To a less extent, and yet to a very perceptible extent, ordinary and not fatiguing exercise increases the fullness of the respiratory effort; that is, it increases the reciprocal action of the abdominal muscles and the diaphragm. There is thus an increased motion mechanically given to the stomach and intestines. The effect of this is to increase the supply of blood sent to these organs, and thus to favor digestion and prevent dyspepsia. Another effect is to keep their contents in motion, and thus to prevent constipation.

(*b*) The **rhomboideus** (11, 12, Fig. 62) arises from the spinous processes of the three lower cervical and the four upper dorsal vertebræ, and is inserted into the whole posterior edge of the scapula. It draws the scapula upward and backward.

(*c*) The **serratus anticus major** (22, Fig. 62) arises along the sides of the thorax from the eight superior ribs, runs back under the scapula and is inserted into the posterior edge of it. It moves the scapula downward and forward.

2. Muscles which move the shoulder-joint.

(*a*) The **pectoralis major** (1, Fig. 64) arises from the whole length of the sternum and the fibres converging. It is inserted into the fore side of the humerus, about three inches from its upper extremity. It brings the arm downward and forward.

(*b*) The **latissimus dorsi** (4, Fig. 62) arises from the spinous processes of the lumbar vertebræ and sacrum, and from the edge of the ilium, and is inserted into the humerus just back of the insertion of the pectoral muscles. It draws the arm downward and backward.

(*c*) The **deltoides** (5, Fig. 62) arises from the spine of the scapula, the acromion, and the outer extremity of the clavicle, passes over the shoulder-joint, and is inserted into the outer side of the humerus near the middle. It raises the arm.

3. Muscles which move the elbow-joint.

(*a*) The **biceps flexor cubiti** (8, pl. II.) arises from the upper edge of the glenoid cavity and from the coracoid process of the scapula, and, passing the whole length of the humerus, it is inserted into the tuberosity at the upper end of the radius. It bends the forearm.

(*b*) The **brachialis internus**, situated under the biceps, arises from the humerus, near the insertion of the deltoid muscle, and is inserted near the upper extremity of the ulna, on the front side. Its use is the same as the previous muscle.

(*c*) The **triceps extensor cubiti** (7, pl. I.) arises from the lower edge of the glenoid cavity, from the upper extremity and from the middle of the humerus, and is inserted into the olecranon. It extends the forearm.

4. Muscles which move the wrist and fingers.

The muscles of this division have three objects, to rotate the hand, to move the wrist, and to move the fingers. Seven of these arise from the internal condyle, of which the first is a pronator and the rest are flexors.

(*a*) The **pronator teres radii** (7, pl. II.) passes obliquely over the forearm, and is inserted near the middle of the radius. It rolls the hand inward.

(*b*) The **flexor carpi radialis** (9, pl. II.) follows down near the radius, passes under the annular ligament, and is attached to the metacarpal bone of the forefinger. It bends the wrist.

(*c*) The **flexor carpi ulnaris** takes its course along the ulna, and is inserted into the pea-shaped bone of the wrist. It bends the wrist.

(*d*) The **palmaris longus** has nearly the same course as the preceding muscle, and is inserted into the membranous expansion which lies in the palm of the hand, and has also a slender attachment to the bones of the hand. It helps to bend the wrist.

(*e*) The **flexor digitorum sublimis** (10, pl. II.) passes as one muscle to the middle of the forearm, when it divides into four parts, which soon become tendonous, pass under the annular ligament, and are inserted one into the second phalangeal bone of each finger. It bends the fingers at the first and second joints.

(*f*) The **flexor digitorum profundus** lies under the sublimis, is also divided into four tendons, and they are inserted into the last bone of each finger. It therefore bends the last joint.

(*g*) The **flexor longus pollicis** is inserted into the last bone of the thumb. It bends all the joints of the thumb.

The next six muscles arise from the external condyle of the humerus, of which the first is a supinator, and the rest are extensors.

(*a*) The **supinator radii longus** (8, pl. I.) passes obliquely over and nearly around the forearm, and is inserted into the lower end of the radius. It rolls the hand outward.

(*b*) The **extensor carpi radialis** descends along the back of the radius, and is inserted into the metacarpal bone of the forefinger on the back of the hand. It extends the hand.

(*c*) The **extensor carpi radialis brevior** resembles the last, except that it is inserted into the metacarpal bone of the second finger. It extends the hand.

(*d*) The **extensor carpi ulnaris** descends along the ulna, and is inserted into the metacarpal bone of the little finger. It extends the hand.

(*e*) The **extensor digitorum communis** (9, pl. I.). At the middle of the forearm it divides into three tendons, which are inserted into the middle bones of the first, second, and third fingers. A strip of tendon also reaches to the last bones of the same fingers. It extends all the joints of these fingers.

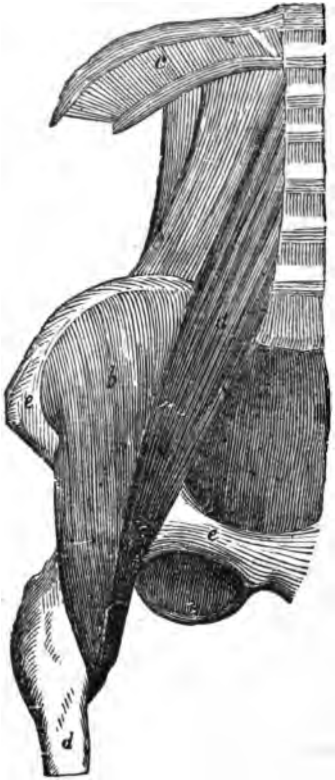
(*f*) The **extensor minimi digiti** is inserted in a similar manner into the bones of the little finger, and extends all the joints.

(*g*) The **extensores pollicis** arise from the middle of the ulna, and are inserted, one into the metacarpal bone of the thumb, and one into each of the other bones of the thumb, and extends all the joints.

91. XII.—*Muscles of the lower extremities.*

1. Muscles which move the thigh.

Fig. 65.



a The psoas magnus muscle. *b* The iliacus internus. *c* One of the intercostal muscles. *d* Part of the femur. *e*, *e* The bones of the pelvis.

(*a*) The **psoas magnus** (*a*, Fig. 65) arises from the front side of the bodies and transverse processes of the lumbar vertebræ, runs across the pelvis to the os pubis, bends over the anterior edge of this bone, and is inserted into the trochanter minor of the femur. It brings the thigh forward.

(*b*) The **iliacus internus** (*b*, Fig. 65) arises from the whole internal surface of the wing of the ilium. Its fibres converge, become tendonous, and unite with the tendon of the psoas magnus. Its action is, therefore, the same as the psoas.

(*c*) The **gluteus maximus** (13, pl. I.) arises from the external surface of the sacrum and coccyx and the lower external surface of the ilium, and is inserted into the upper part of the linea aspera for a third of the length of the thigh. Its use is to straighten the thigh and draw it backward. But as important an office is, in connection with other muscles, to support the body in an erect position on the lower extremities.

(*d*) The **gluteus medius** (12, pl. I.) arises from the outer surface of the spine of the ilium, and is inserted into the back part of the trochanter major. It carries the thigh outward, and also turns the toes outward.

(*e*) The **gluteus minimus** arises from that part of the ilium contiguous to the acetabulum, and is inserted into the front side of the trochanter major. The effect of this muscle is to turn the thigh so as to carry the toes inward.

(*f*) The **triceps adductor** arises from the upper and front part of the os pubis, by three heads, and is inserted into the whole length of the linea aspera. It rotates the thigh, and brings it inward.

(*g*) The **obturator externus** arises from the large foramen in the os ischium, passes under the neck of the femur, and is inserted into the inner and back part of the trochanter major. It rotates the thigh outward.

2. Muscles which move the leg.

(*a*) The **sartorius** (11, pl. II.) arises from the upper and front part of the ilium, winds obliquely to the inside of the leg, and is inserted into the inner tubercle of the tibia. It bends the leg, and draws it obliquely inward.

The next four muscles lie on the under side of the thigh, and their office is to bend the knee.

(*b*) The **gracilis** (14, pl. I.) arises from the os pubis near its inferior part.

(*c*) The **semi-tendinosus** (17, pl. I.) arises from the lower extremity of the ischium.

(*d*) The **semi-membranosus** also arises from the lower extremity of the ischium. These three muscles, together with the sartorius, have a common insertion at the inner tubercle of the tibia, by a common tendon which forms the inner hamstring.

(*e*) The **biceps cruris** (16, pl. I.) arises from the lower extremity of the ischium, and from the linea aspera near the insertion of the gluteus maximus, and is inserted into the outer tubercle of the tibia. Its tendon constitutes the outer hamstring.

The remaining four muscles constitute the extensor of the leg.

(*f*) The **rectus femoris** (12, pl. II.) arises from the front part of the ilium.

(*g*) The **crureus** —— arises from the trochanter minor.

(*h*) The **vastus internus** (13, pl. II.) also arises from the trochanter minor.

(*i*) The **vastus externus** (14, pl. II.) arises from the trochanter major.

These four muscles unite in one great tendon, which is inserted into the patella. A short tendon connects the patella with the tibia where the power is to be exerted.

3. Muscles which move the foot.

(*a*) The **gastrocnemius** (19, pl. I.) arises from both condyles of the femur.

(*b*) The **soleus** arises from the tubercles of the tibia.

These muscles unite in a strong tendon (the tendon Achillis, 21, pl. I.) which is inserted into the extremity of the heel (the os calcis). (The tendon is seen above, 3, Fig. 42.) They extend the foot.

(*c*) The **peroneus** (20, pl. I.) arises from the head of the fibula. It follows this bone to its lower extremity, passes through the channel of the outer ankle, turns under the foot, and is inserted into the metatarsal bone of the great toe. It extends the foot, and presents the sole obliquely outward.

(*d*) The **tibialis posticus** arises from the upper extremity of the tibia, passes down on the back side between the tibia and fibula, turns under the foot just back of the malleolus internus, and is inserted into the middle of the under side of the foot. It extends the foot slightly, and presents the sole obliquely inward.

(*e*) The **tibialis anticus** (19, pl. II.) arises from the head of the tibia on the front side, passes down forward of the malleolus internus, and is inserted with the posticus. It flexes the ankle slightly, and turns the sole inward.

4. Muscles which move the toes.

(*a*) The **flexor pollicis pedis** arises a little below the head of the fibula on the back side, passes behind the ankle-joint on the inside to the bottom of the foot, and is inserted into the under side of the last bone of the great toe. It bends this toe.

(*b*) The **flexor digitorum pedis** resembles the flexor pollicis pedis till it reaches the bottom of the foot, where it divides into four tendons, which are inserted one into the last bone of each toe except the first. It bends these toes.

(*c*) The **extensor pollicis pedis** (16, pl. II.) arises from the front side of the head of the fibula, passes along the bone to the ankle, then under the annular ligament, and is inserted into the upper side of the last bone of the great toe. It extends the great toe, and bends the ankle.

(*d*) The **extensor digitorum pedis** (17, pl. II.) is like the pollicis pedis till after it passes under the annular ligament, where it divides into four tendons, which are inserted one into the top of the last bone of each toe except the first. It extends the toes and bends the ankle.

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Epiph'ysis. (Gr. *επι*, upon, and *φυω*, to grow.) A prominence of bone.
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Eth'moid. (Gr. *ηθμος*, a sieve.) A bone of the cranium. 13.
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Extrav'asation of blood, the escape of blood from its proper vessels into the cellular tissue.
Expiration, the act of expelling air from the lungs.
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Farina'ceous, consisting of farina, starch.

Fas'cia. (L.) A band of tendinous substance.
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Fasci'culus. (L. a small bundle.) A collection of minute muscular fibres. 68.
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Gel'atine, an animal product, soluble in water, glue.
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Glosso-pharynx, belonging in common to the tongue (glossa) and the pharynx.
Glot'tis, the opening into the larynx. Fig. 103.
Glu'ten, the tough substance obtained from wheat by chewing the kernels.
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Hepat'ic, pertaining to the liver.
Herbiv'orous, a term applied to animals which require vegetable food.
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Hydraulic, relating to the conveyance of liquids.
Hy'drogen, one of the elements of water.
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Locomotion, motion from place to place.
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" spongy bones, 27.
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Mag'num foramen. (L.) The larger aperture in the bone of the cranium through which the spinal cord enters, 15.
Malar. (L. *mala*, the cheek.) Pertaining to the cheek. 25.
Mal'leus. (L. a hammer.) The first bone of the tympanum. 140.
Mastica'tion. (L. *mastica'tio.*) The act of chewing. 183.
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